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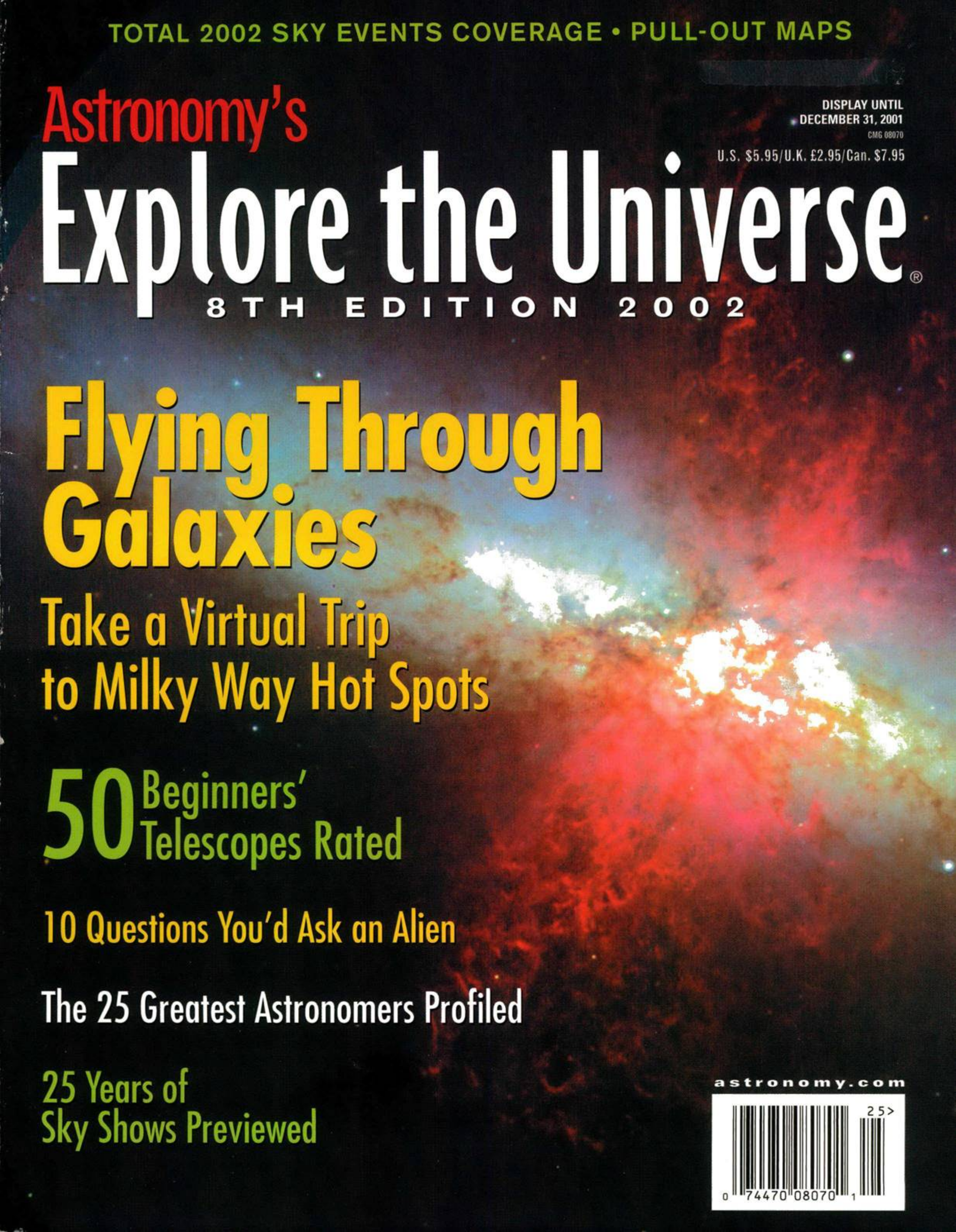

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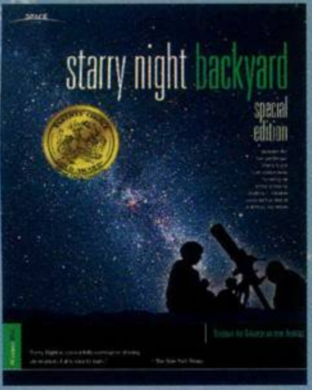
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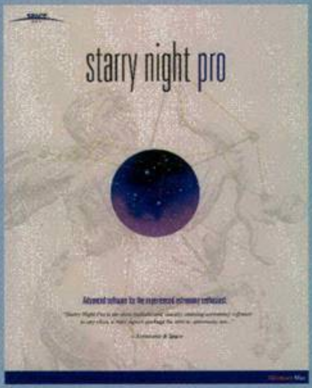
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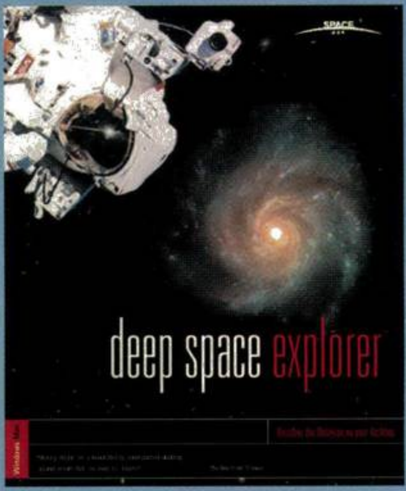
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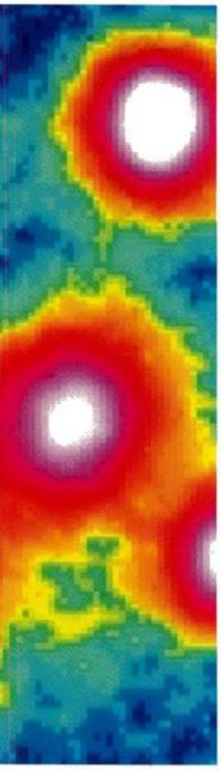

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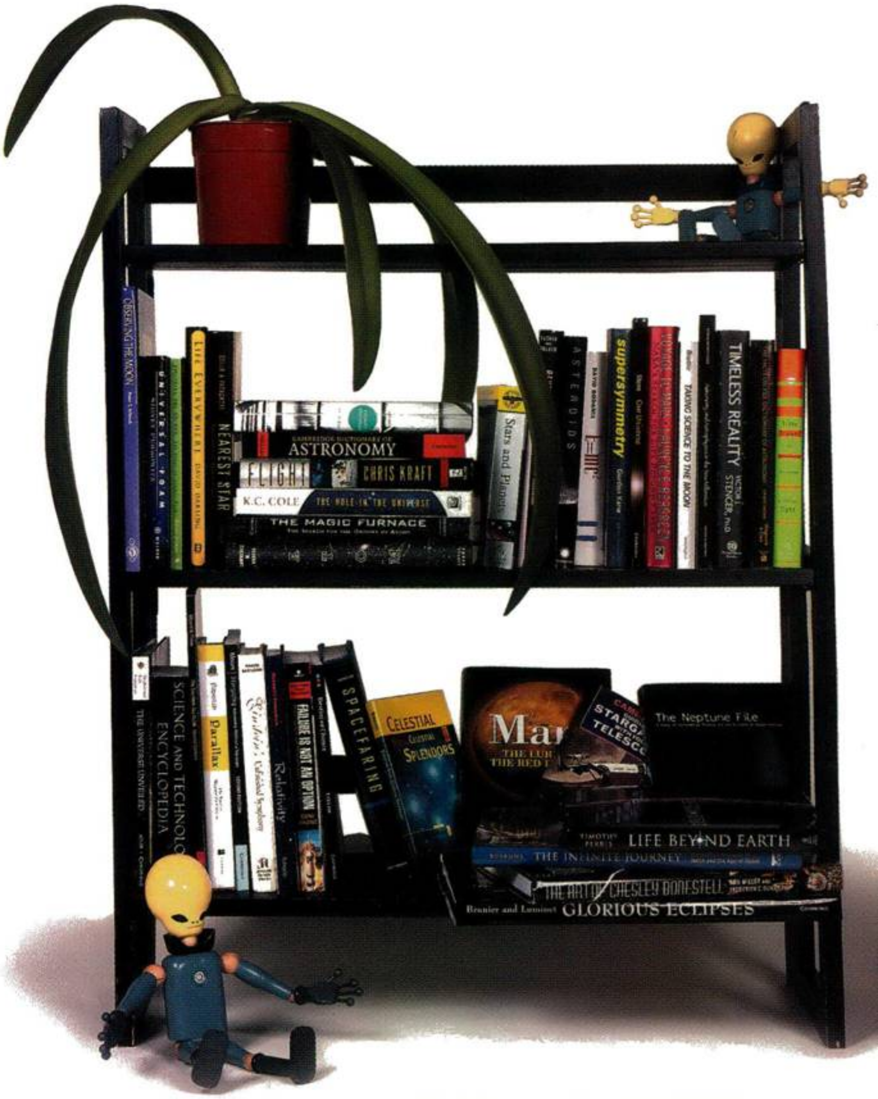
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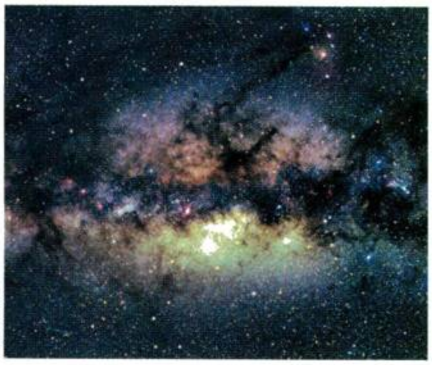
At *the* Eyepiece

Following the Milky Way

Every amateur astronomer has a soft spot for the Milky Way. When most astronomers first get turned on to observing by catching a glimpse of Saturn, seeing the misty glow of the Orion Nebula, or spotting the elusive light of a distant galaxy, they find there's something ethereal — almost magical — about lying out on the cushion of a sleeping bag, staring upward at the gentle summer radiance of the Milky Way arching overhead. As a teenager sneaking out into the farm fields of southwestern Ohio, I spent many nights befriending the glows of the home galaxy (accompanied by my border collie Oscar, who kept the raccoons at bay). Eyes alone are sufficient to show a spectacular amount of detail on a truly dark night. Some of the brightest stars in our galactic neighborhood — Vega, Deneb, Altair — punch through the unresolved skyglow of millions more stars, all floating in a distant, frozen frame of spacetime.


Axel Mellinger

Milky Way riches in Sagittarius.

Milky Way viewing is hardly limited to summertime. The winter sky holds some of the greatest riches of the galaxy, from Orion's majestic nebulae to the brilliant star clusters of Canis Major and Puppis. Users of small telescopes can lose themselves in hundreds, perhaps thousands, of galactic targets that will show them a virtual "who's who" of the galaxy.

In this eighth special issue of *Astronomy* magazine, Italian science writer Alexander Hellemans (a frequent contributor to *Science*) has written a rapid-paced tour of eight major objects in the galaxy that have become significant targets for astronomical research. Hellemans offers us a spaceship of the imagination in which we can travel to increasingly distant prey. He takes us into the local bubble surrounding the sun's neighborhood to meet an extremely low-mass star, then outward past a proto-solar system, stellar nurseries and corpses, a black hole, ancient suns locked in a globular cluster, the most massive star known in the galaxy, and the tumult of the galactic center, where a hidden monster reveals itself only to certain wavelengths. It's a whirlwind tour that affords a peek at some of the most intriguing current mysteries weighing on galactic astronomy research.

Turn back to page 72, then, to find expert observer Tom Polakis's visual tour of the Milky Way's greatest hits. Having explored the galaxy intellectually, we invite you to unlimber your binoculars or telescope and spot some of the two dozen stars, clusters, and nebulae Polakis describes.

We don't exclude equipment: Phil Harrington's compilation on p. 84 surveys 50 top telescope choices for beginners, including full coverage of the popular "go-to" types with built-in computer databases. Senior editor Richard Talcott's story previews the greatest sky events coming over the next 25 years (turn to p. 34 and pull out your Palm Pilot); the events of this year are treated in detail, as always, in *Astronomy's* 2002 Skyguide, by Martin Ratcliffe — 25 pages of the most comprehensive information in the business (p. 39). Oh, we also landed a very rare interview with an alien, who has some interesting thoughts on planet Earth — the transcript appears on p. 66. I wonder if this alien arrived from a planet orbiting that little star I used to tell my dog about back in some Ohio cornfield . . .

Dave Eicher, Editor

Explore the Universe
8TH EDITION 2002

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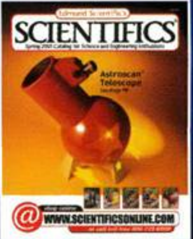

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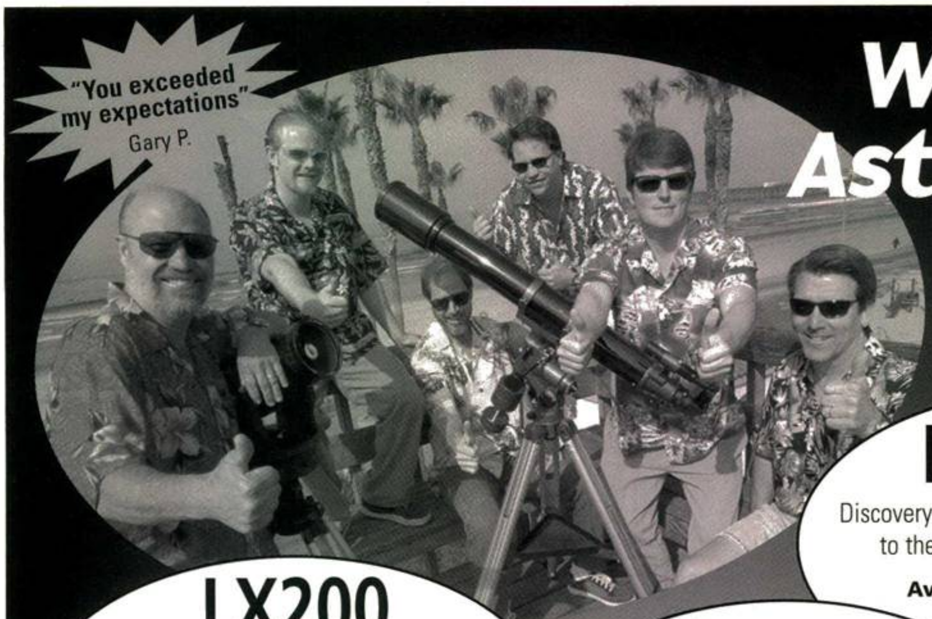

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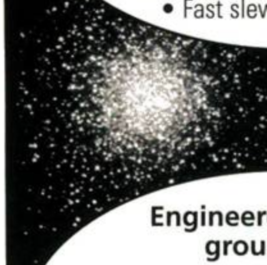
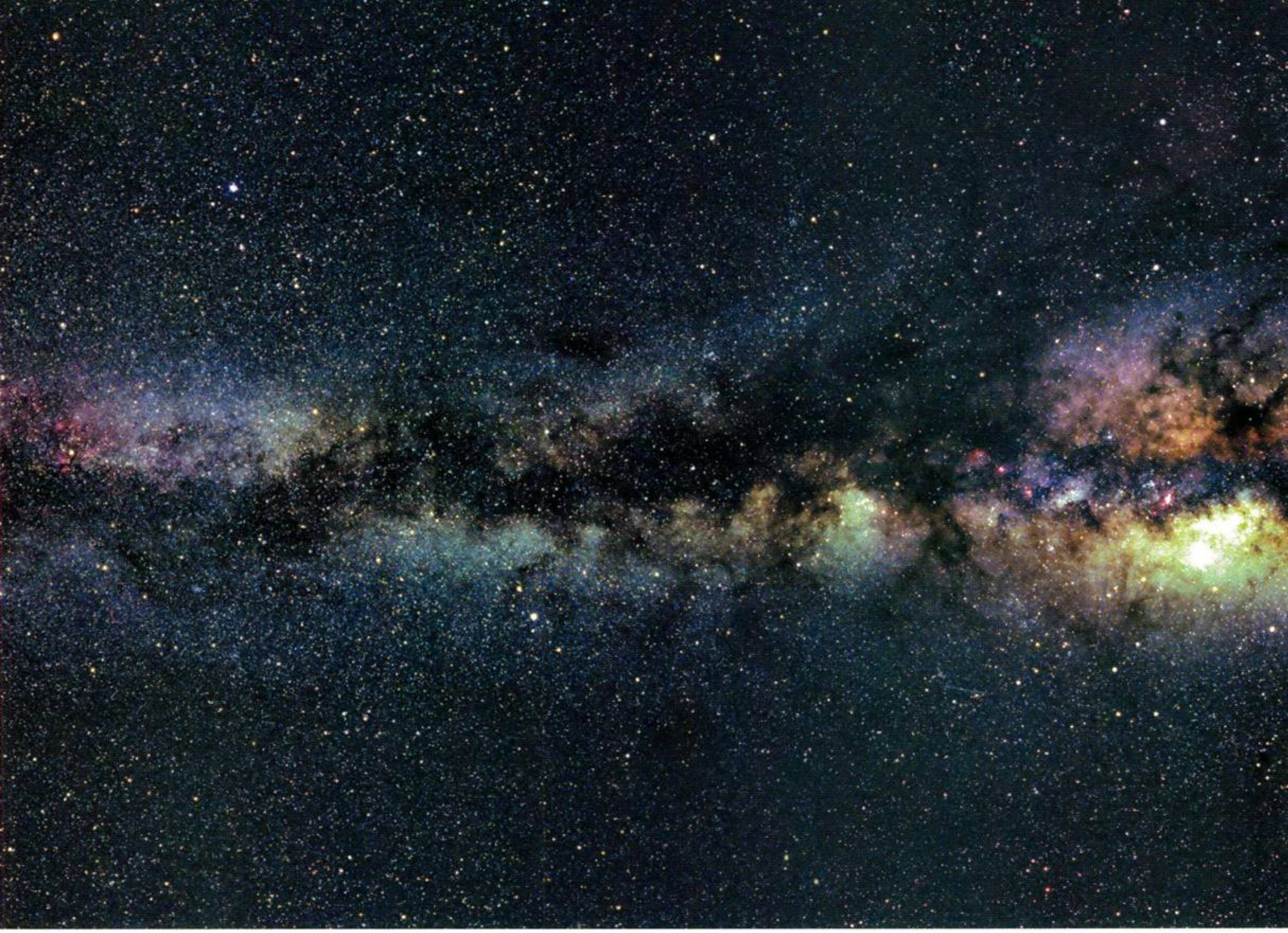




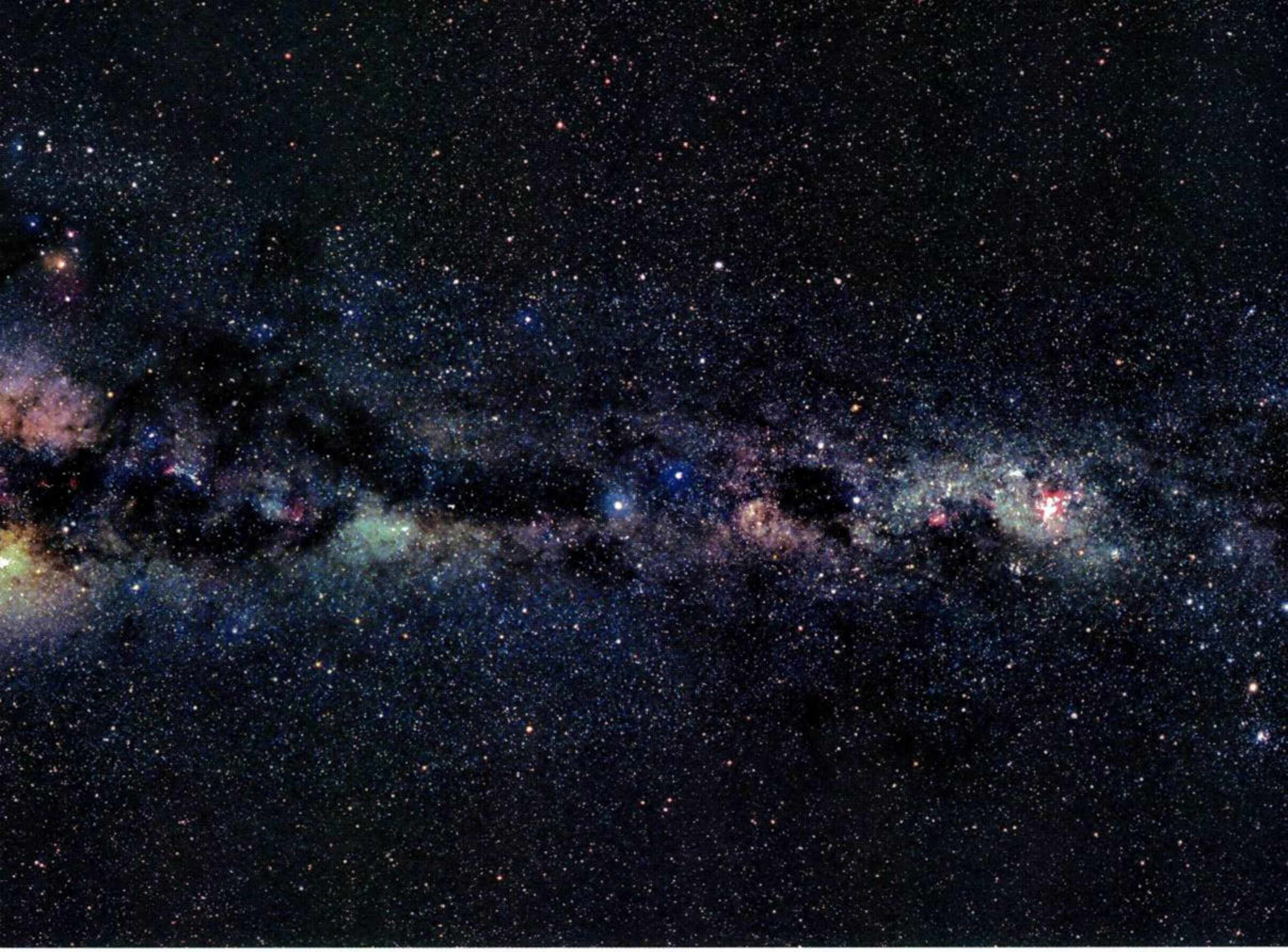
CRUISING THRO

The Milky Way's hottest objects await a spacecraft of the imagination.

by Alexander Hellemans

During the last few decades, our view of the galaxy has changed drastically. New windows opened up, first by radio telescopes, and later by spacecraft pointing ultraviolet, x-ray, and gamma-ray instruments above Earth's atmosphere. Infrared telescopes allow astronomers to pierce obscuring dust and gas. The Hubble Space Telescope and a new class of very large, ground-based telescopes have improved our capabilities in visible light. Chandra, with its revolutionary x-ray optics, allows us to resolve x-ray sources in minute detail.

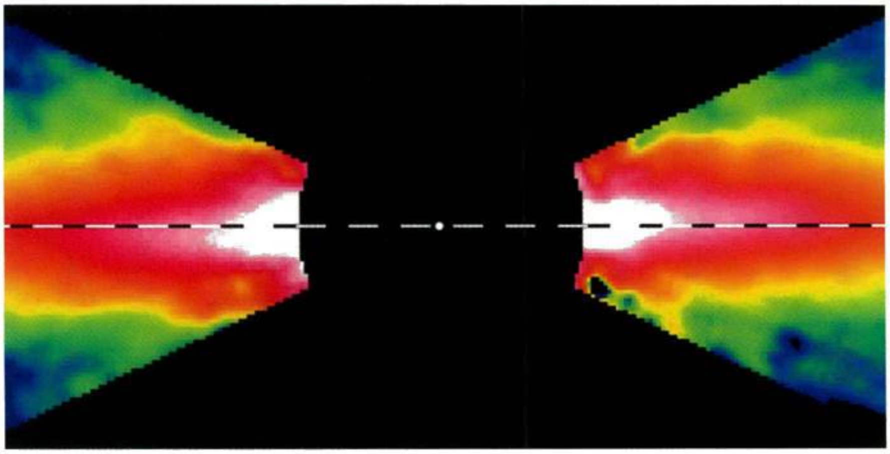
All these new observations show us that our galaxy is a


Axel Mellinger

UGH THE GALAXY

much more exciting place than previously thought. We now know that our solar system is not unique — other solar systems with planets abound (although these planets are very different than ours). Our view of the galaxy as a large collection of stars quietly burning their nuclear fuel has altered — stars explode, leaving huge clouds of gas and dust. Some star systems called "microquasars" produce huge jets that travel over enormous distances. And most astronomers are convinced that a black hole with the mass of millions of suns resides at the center of our galaxy.

Some of the most intriguing objects in the galaxy lie scattered across a wide range of space such that a spaceship of the imagination can carry us on a trip of discovery to them. Sit back, relax, and get ready to cruise through areas of the galaxy that may be unknown or familiar, all of which cast a glow onto recent astronomical research.



Chris Burrows/STScI, and NASA

The inner regions of the disk of dust and planets around Beta Pictoris show in this Hubble Space Telescope image.

13 LIGHT-YEARS
A LOW-MASS NEIGHBOR

Our neighborhood, the so-called "local bubble," is a region streching 1,500 light-years outward that is almost void of gas and dust. However, we have some interesting neighbors — stars that are very different from our sun, which is a very ordinary star. Xavier Delfosse and Thierry Forveille of Grenoble Observatory discovered the star as an unusual bright and red object in ESO's DENIS survey, (DEep Near-Infrared Survey). The object, far too faint to be observed with a small telescope, is known as DENIS-P J104814.7-395606.1, and is a very-low mass star of about 60 to 90 Jupiter masses.

Jean Guibert and Françoise Crifo of the Observatory of Paris studied the object on photographic plates taken over the last 30 years and found that its proper motion indicated that it could not be more than about 13 light-years away from us. The nature of the object remained puzzling: Was it a brown dwarf, an object that is heated by gravitational contraction only, or a low-mass star in which nuclear reactions take place in its core? "It was a borderline case, and we didn't know at what side of the border it was," says Delfosse.

Fortunately, astronomers have a way to tell whether nuclear reactions have taken place in a star by looking for lithium lines in its spectrum. Most of the lithium in space was formed shortly after the Big Bang, but is burned up in stars by nuclear reactions.

Eduardo Martin, a Spanish astronomer at the Institute of Astronomy at the University of Hawaii who developed the so-called "lithium test," could not find any trace of the element in the faint object studied by the French astronomers. He concluded that it had to be at least 60 times greater than Jupiter's mass. "It is a common object, really, but it is faint, and it is part of the dark-matter mystery," says Martin. Because they are relatively massive but very faint, many such objects could populate the galaxy, making up a good part of its missing mass, comments Martin.

53 LIGHT-YEARS
BETA PICTORIS: A SOLAR SYSTEM IN THE MAKING

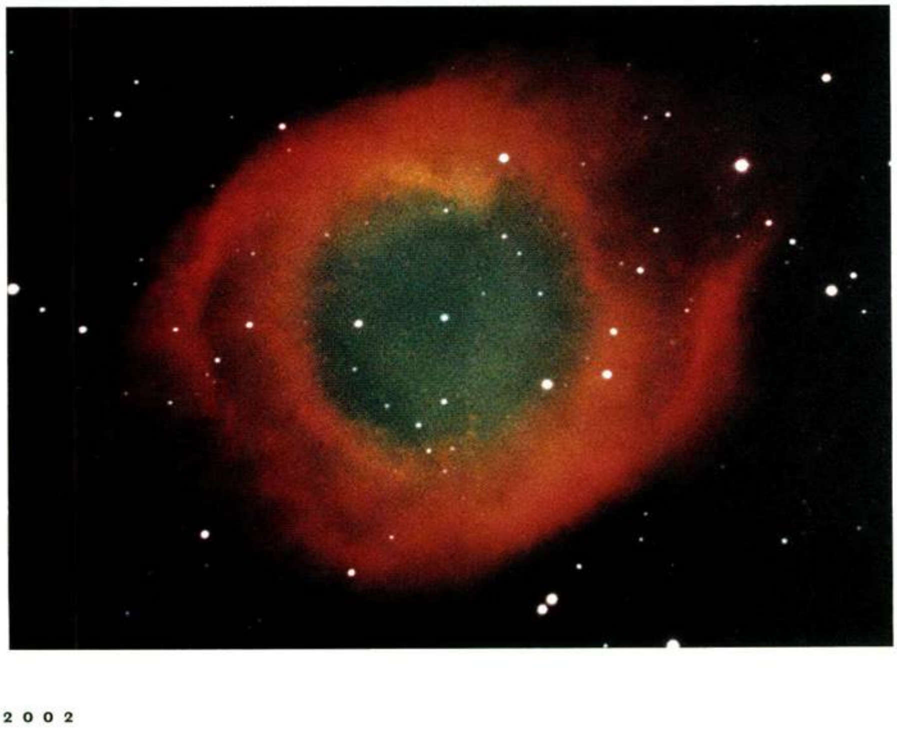
At a distance of 53 light-years, the 4th-magnitude star Beta Pictoris has attracted considerable attention of planet hunters. The star is surrounded by a huge disk of dust and gas. It extends across 1,300 astronomical units (one astronomical unit is the distance between Earth and the sun, some 93 million miles) and is the brightest disk of any nearby star known. Bradford Smith at the University of Arizona and Rich Terrile of the Jet Propulsion Laboratory discovered the disk in 1983.

The star is surrounded by a clear zone about the size of our solar system, which in turn is surrounded by a disk. It is interesting for planet hunters because "it is a very dusty disk, and you can outline the morphology of the disk in detail," says Sara Heap of NASA's Goddard Space Flight Center. The presence of dust makes the formation of planets very likely. "Since the disk is about 20 million years old, we know that if planets could form, they would have formed by now," she adds.

The fact that the disk is distorted indicates the presence of a planet, says Heap: "The inner region is tilted with respect to the outer region, and that indicates that there is something there." Calculations show that the warp could be caused by a planet of about 10 Earth masses at a distance of 50 astronomical units from Beta Pictoris.

The disk also contains comets. They give themselves away when they pass in front of the face of the star. "The comet tails absorb light from the star at specific frequencies, and you see spectral absorption," says Heap.

The Helix Nebula (NGC 7293) in Aquarius, the closest planetary nebula, is a challenge for visual observers.



Ken Blankenship and Dennis Batis

450 LIGHT-YEARS THE HELIX NEBULA (NGC 7293)

Among the most spectacular galactic objects are planetary nebulae — huge clouds that are the remnants of dying stars that have belched off layers of gas. One of them, the Helix Nebula, is a faint object, only visible in a very dark sky. However, at 450 light-years, it is the closest bright remnant of a collapsed star. Long arcs, with the appearance of a helix viewed from an angle, are visible in the nebula, but their nature is still not understood. "As such we probably see more detail in this object than we can in any other nebulae," says Robert O'Dell of Vanderbilt University in Nashville, Tennessee.

One of the peculiar features in this nebula is the "cometary knots," comet-like features initially spotted by Walter Baade on Palomar Mountain's 200-inch telescope images, and of which the nature is not yet entirely understood. The fact that they all have this typical shape of a comet— a head and a long tail pointing away from the star, and also, that they seem to have a similar size, is really puzzling, says Garrelt Mellema of Leiden University in the Netherlands.

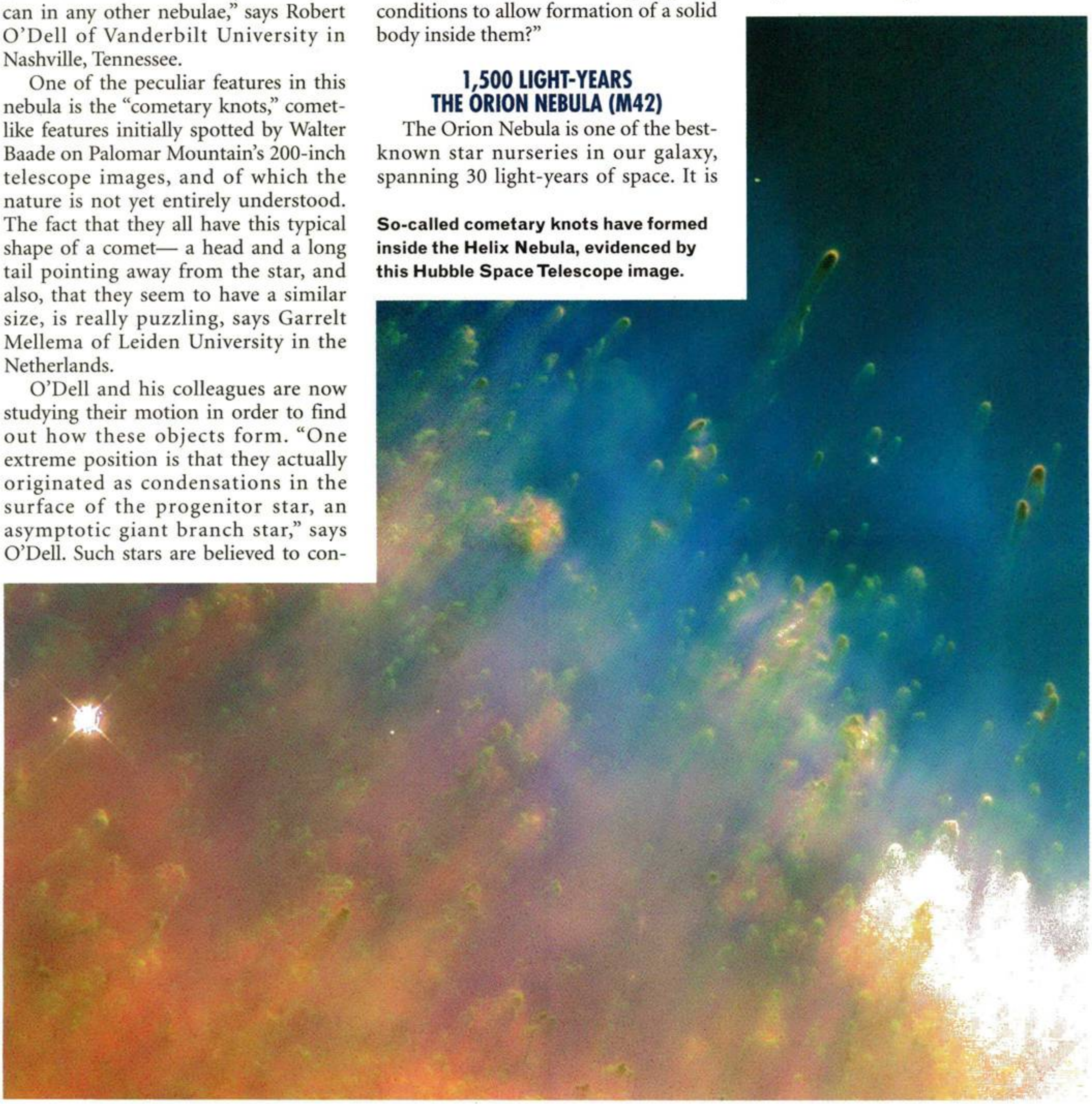
O'Dell and his colleagues are now studying their motion in order to find out how these objects form. "One extreme position is that they actually originated as condensations in the surface of the progenitor star, an asymptotic giant branch star," says O'Dell. Such stars are believed to contain condensations in their extended atmospheres. Another possibility is that they are the same type of objects as comets. However, the mass of these knots "seems to lie between that of the Earth and Jupiter, which is much more than the mass of a comet," says Mellema. He believes that these objects are gas masses hit by the ionizing radiation of the star, and that the tail-shaped regions are in fact "shadow regions" protected from the ionizing radiation.

"There is the tantalizing possibility that solid cores could form inside these objects," says O'Dell. "The question is: will they have time and the appropriate conditions to allow formation of a solid body inside them?"

1,500 LIGHT-YEARS THE ORION NEBULA (M42)

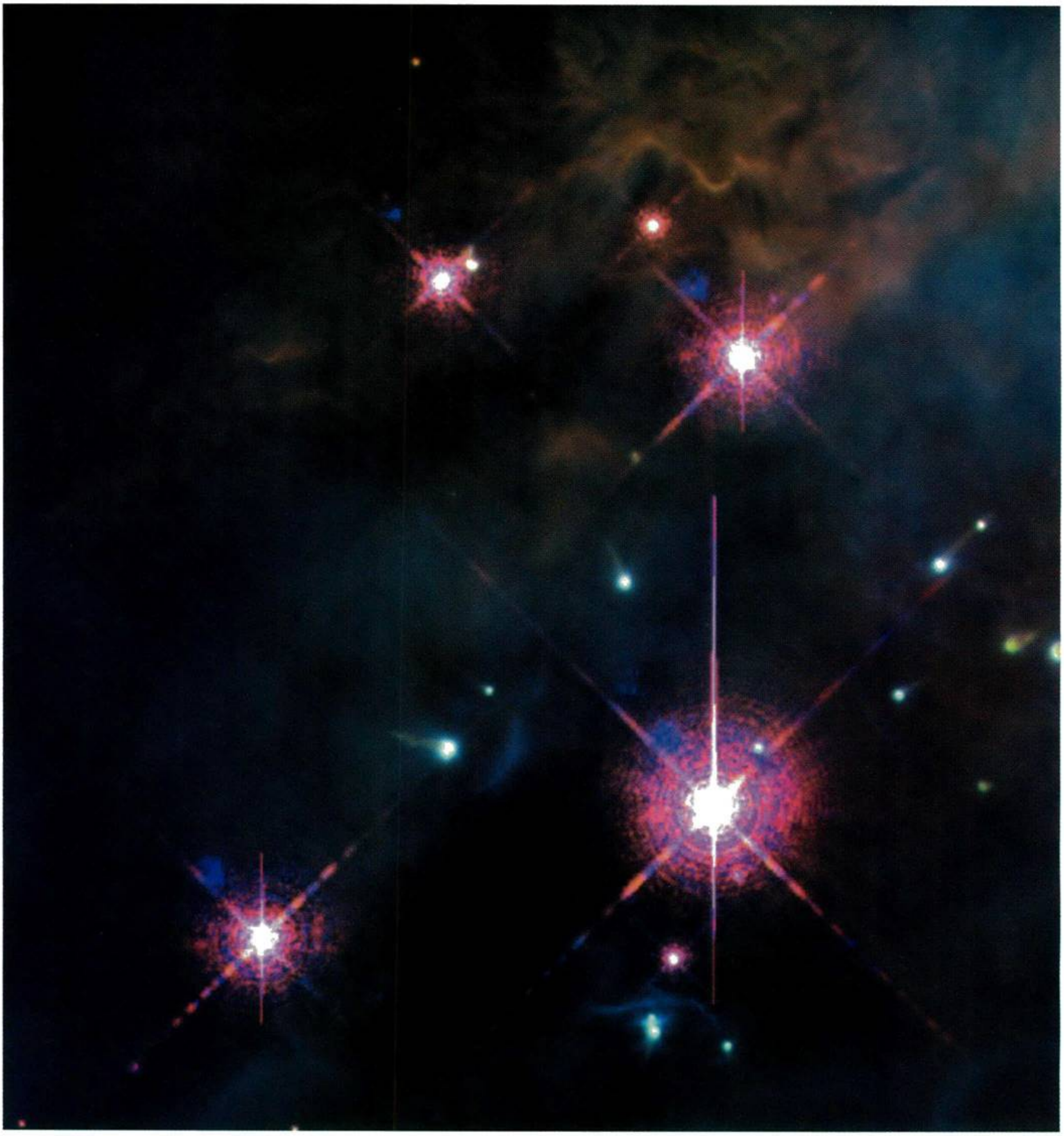
The Orion Nebula is one of the best-known star nurseries in our galaxy, spanning 30 light-years of space. It is also the nearest one, and hundreds of stars are now being born there. Now astronomers have a unique new tool to probe the births of stars. Sheperd Doeleman of the MIT Haystack Observatory reports how he observed a newly born star in Orion emitting radio waves.

The massive young star in Orion is ejecting a fast stellar wind from its north and south poles. This wind burrows through the nebula, and masers, an anomolously high energy source of radiation, form at the interface between wind and nebula. "It turns out this is a very turbulent region, but the masers



So-called cometary knots have formed inside the Helix Nebula, evidenced by this Hubble Space Telescope image.

Robert O'Dell, Kerry P. Handron, and NASA



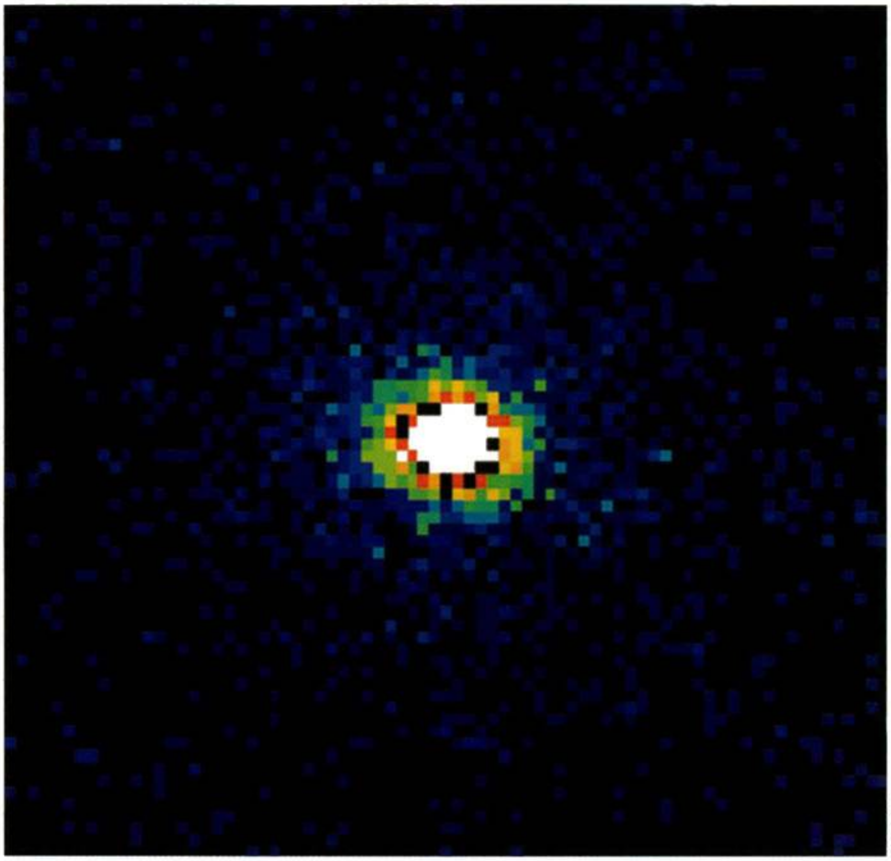
Doug Johnstone, Univ. of Toronto/NASA

Failed stars called "planetars" float freely within the Orion Nebula, near the familiar bright stars of the Trapezium.

are very bright and very small, so they allow us to measure this turbulence on very small scales — much less than an astronomical unit," says Doeleman.

In order to pinpoint these maser sources, astronomers combine radio telescopes the world over. They are "creating a huge supertelescope with an angular resolution a thousand times larger than the Hubble Space Telescope," says Doeleman.

However, besides the massive stars that are born in Orion, the nebula is also filled with objects that didn't make it to become a star. Although these bodies contract from masses of gas and dust and heat up because of gravitational contraction, their masses are just too low to start up nuclear reactions in their cores. Recently astronomers found 20 such free-floating planet-like objects in the Orion Nebula. Their masses are smaller than the so-called brown dwarfs — failed stars with masses of at least 13 Jupiter masses — and are called "planetars," with masses up to 8 times that of Jupiter. Astronomers believe they may have been formed the same way as stars. They give themselves away because of spectral lines in their spectra that reveal the presence of water. Since the stars in Orion are very young, these objects haven't cooled down very much, and can therefore be observed easily,



EXOSAT

Recognized as a strong x-ray source in 1972, Cygnus X-1 became the first known black hole.

explains Phil Lucas of the University of Hertfordshire in the U.K. "We can fairly directly measure the temperature from the spectrum, but our assumption of very low mass depends on evolutionary calculations," says Lucas.

6,000 LIGHT-YEARS CYGNUS X-1

In 1972, when the Uhuru X-ray Observatory focused on a highly variable x-ray source in the constellation Cygnus, astronomers quickly understood that they had stumbled upon their first black hole. Called Cygnus X-1, the source is a binary system in which the x-rays are produced by matter flowing from a supergiant star to a black hole. The matter spirals in a disk-like region around the black hole — the accretion disk — and heats up, emitting x-rays, before being swallowed by the black hole. However, astronomers could not explain the rapid flickering of the x-rays emitted by these sources.

Astronomers Phil Uttley and Ian McHardy of Southampton University in the U.K. had observed that active galaxies also flicker, but at a much larger timescale. These galaxies contain a very massive black hole at their centers that swallow matter surrounding it. The Southampton astronomers noticed that the x-ray variability, typically with a time scale of a few hours, depended directly on the x-ray output of the galaxy. "We took a snapshot observation once a day, and because the active galaxies vary very slowly, we can track these variations quite easily; we can see them with the naked eye," says Uttley. Then, analyzing data with a computer, they found, to their surprise, a similar relationship between variability and x-ray output in Cygnus X-1 and in the millisecond pulsar SAX J1804.4-3658, which contains a neutron star. These observations verified a hunch the astronomers had that the x-ray sources inside our galaxy behave similarly to the active galaxies. "We found a similar kind of pattern in variability, but it happens much more rapidly, a factor of a hundred thousand or a million times more rapidly," says Uttley.

The team analyzed data spanning several hours obtained with NASA's Rossi X-ray Timing Explorer. To their surprise, Uttley and McHardy found a similar relationship between the amount of variability and the x-ray output for both the black hole and the pulsar. "This indicates that it is a property of the accretion process rather than one depending on the nature of the central object," says Uttley.

This observation shows that small black holes found in the galaxy and large ones at the centers of galaxies behave in very similar ways. "We can now say that the x-ray variability is produced by changes in the accretion flow, and that gives us a handle on what is exactly happening in the accretion

Bill and Sally Fletcher

Loaded with delights in backyard telescopes, the Orion Nebula also holds surprises for professional astronomers.

flow," Uttley suggests. "It is now down to the theorists and the physical models they can come up with. We may find what produces the changes in the accretion flow." Processes in which long-term variability are linked to short-term variability are quite common in nature, such as in climate change, and in the patterns of traffic jams, Uttley adds.

15,000 LIGHT-YEARS GLOBULAR STAR CLUSTER 47 TUCANAE

This globular cluster is visible to the naked eye in the Southern Hemisphere; it can be observed close to the Small Magellanic Cloud. It is a 4.5 magnitude object and the second brightest globular cluster, after Omega Centauri. Just like the other 150 globular clusters, it is 12 billion years old, one of the oldest objects in the galaxy. As one of the more massive clusters, and because it is positioned in the halo, its view is not obscured by dust and gas.

Astronomers have always been interested in this cluster because of the very high density of stars in its core, making collisions and interactions more likely. Astronomers believe that these interactions can explain why only 10 percent of the cluster's stars belong to binary systems. This is less than the average of the galaxy (about 30 to 50 percent) because "binaries with very wide separations don't survive, they get broken apart," says Josh Grindlay of the Harvard-Smithsonian Center for Astrophysics.

On the other hand, observations with ROSAT and more recently with Chandra show that the cluster is very rich in x-ray sources. "It has by far the largest number of known millisecond pulsars," says Grindlay. Now 23 of these exotic objects have been detected in the cluster. Here the proximity of stars in the cluster causes the rate of formation of x-ray binaries to be higher than that in the galaxy. "The binary formation is the result of stars passing very close to each other," he says. "The stars either directly capture each other or one star kicks another star out of a pre-existing binary, replacing a normal star with a white dwarf or a neutron star."

What has been intriguing astronomers is the question of whether a black hole exists at the center of the cluster. Chandra observations seem to exclude this; no strong x-ray source can be detected at the cluster's center, reports Grindlay. But strangely enough, no small black holes are found either. "Looking at the x-ray spectra and the variability properties of brighter x-ray sources there has never been a type of x-ray source that looks like a black hole system," says Grindlay.

Though Cygnus X-1 is invisible in optical wavelengths, it lies in a prominent position (arrow) in familiar Cygnus.

Bill and Sally Fletcher

Ron Gilliland and NASA

One of the brightest globular clusters, 47 Tucanae shows its myriad colors in a Hubble Space Telescope shot.

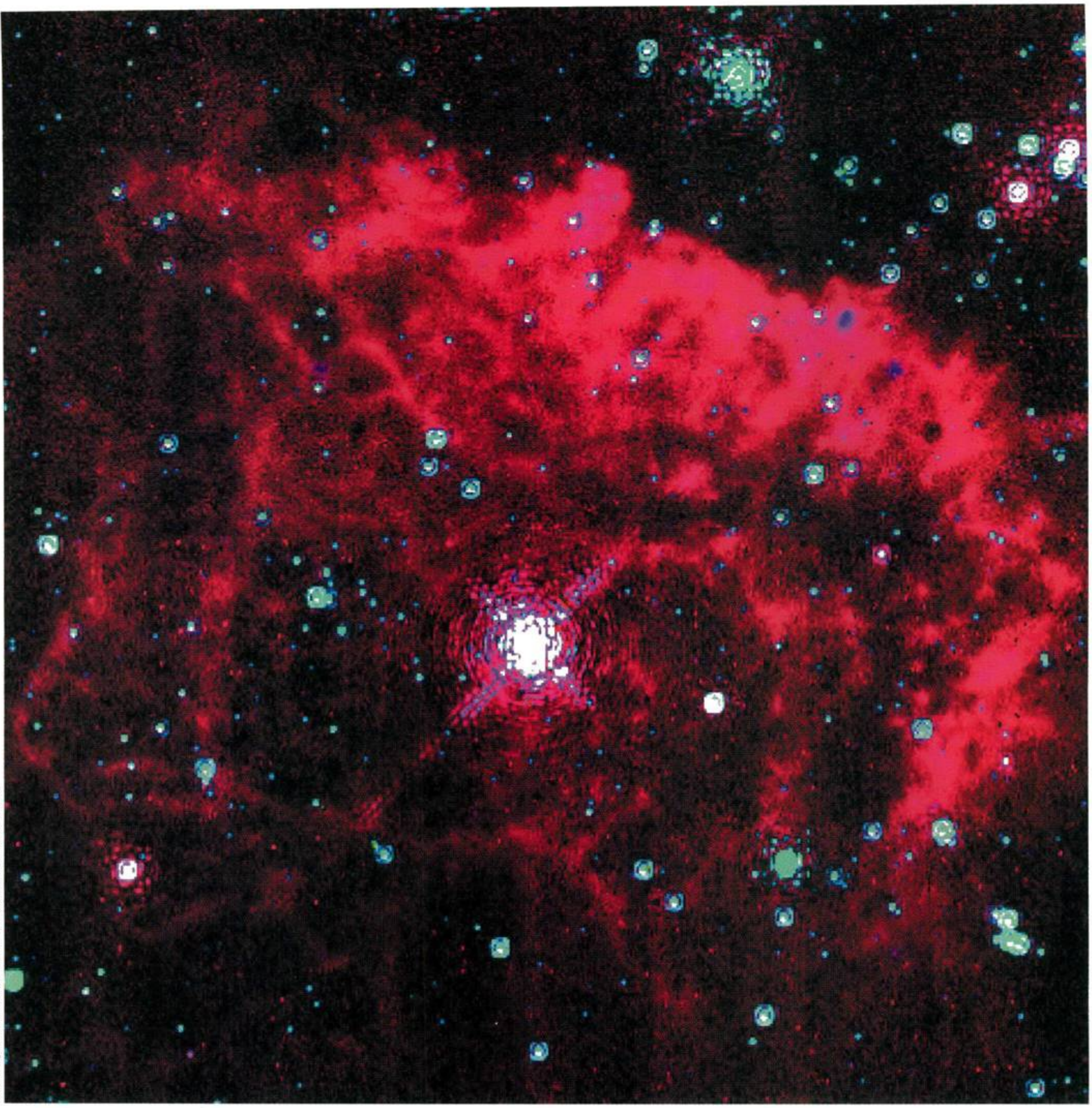
There is the possibility that some black holes were produced in the early primordial cluster. "Black holes, when they encounter each other or other pre-existing binaries, are much more able to kick each other out of the cluster entirely," he concludes.

25,000 LIGHT-YEARS THE PISTOL STAR

Imagine a star 200 times the mass of the sun and whose size would fill the Earth's orbit. A few years ago, astronomers discovered such a stellar monster near the galactic center. Although the star was known for a while, astronomers Mark Morris and Don Figer of UCLA realized it was unusual when studying images they had taken of the object with the Near-Infrared Camera and Multi-Object Spectrometer (NICMOS) aboard the Hubble Space Telescope.

They found that it was a luminous blue variable star. "It is probably an unstable star at the limit of stability or beyond the limit of stability, and we are actually seeing the instability manifest itself," says Morris.

The radiation would be so strong that the radiation pressure would blow off parts of its atmosphere. "The nebula around it shows that five or ten thousand years ago there were violent



Don F. Figer, Mark Morris, and Ian S. McLean, UCLA, and NASA

Pinkish nebulosity surrounds the Pistol Star (center), one of the most massive stars known in the galaxy.

events that ejected a large amount of material," comments Morris, who estimates that the star loses about one solar mass every few thousand years.

Although really massive stars end their lives in supernova explosions, the fast rate at which the Pistol Star is losing mass may even prevent it to reach that stage, believes Morris. Therefore, he reasons, some of these really massive stars may not have contributed any heavy elements to the galaxy. The Pistol Star may then spark a reevaluation of the roles of massive stars in the Milky Way.

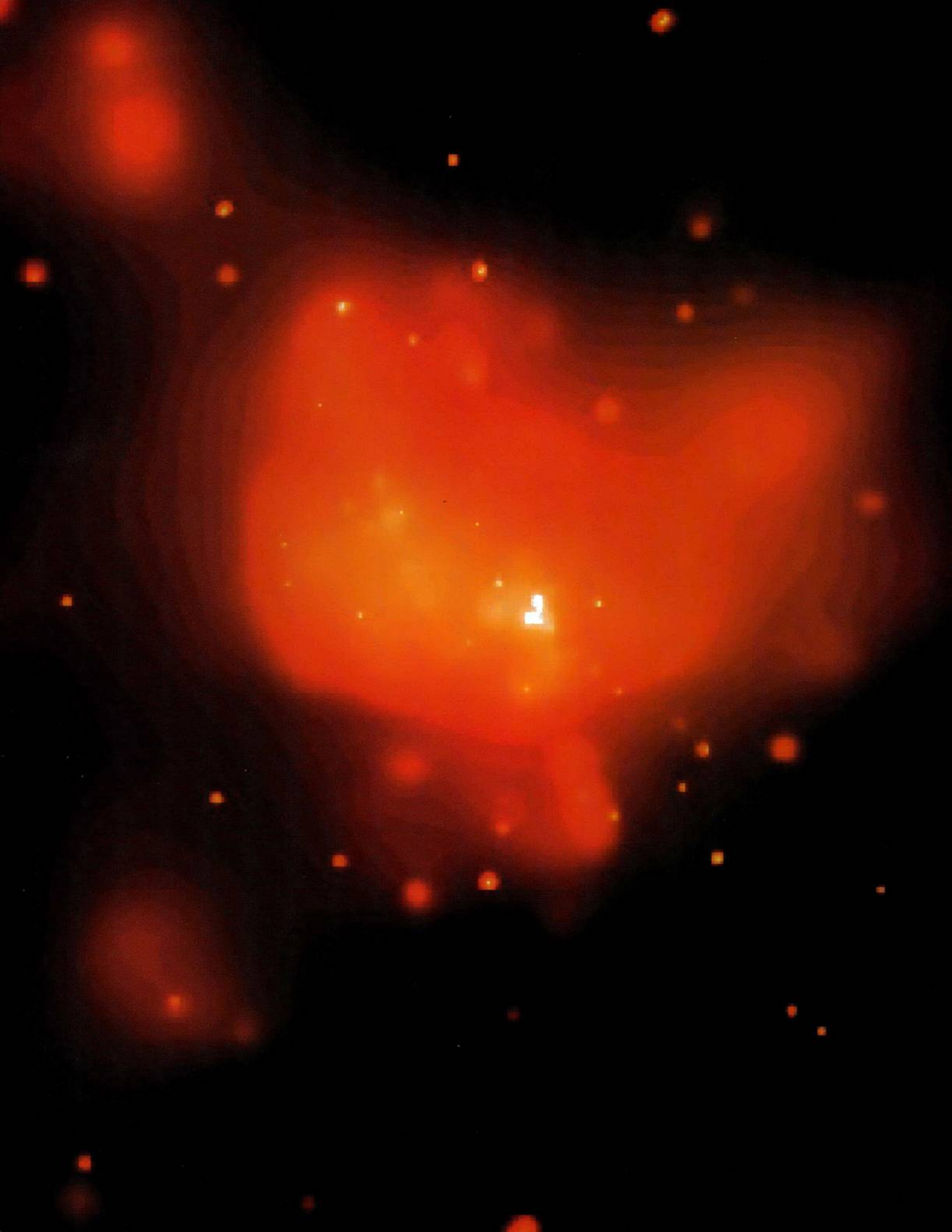
23,000 LIGHT-YEARS THE GALACTIC CENTER (SAGITTARIUS A*)

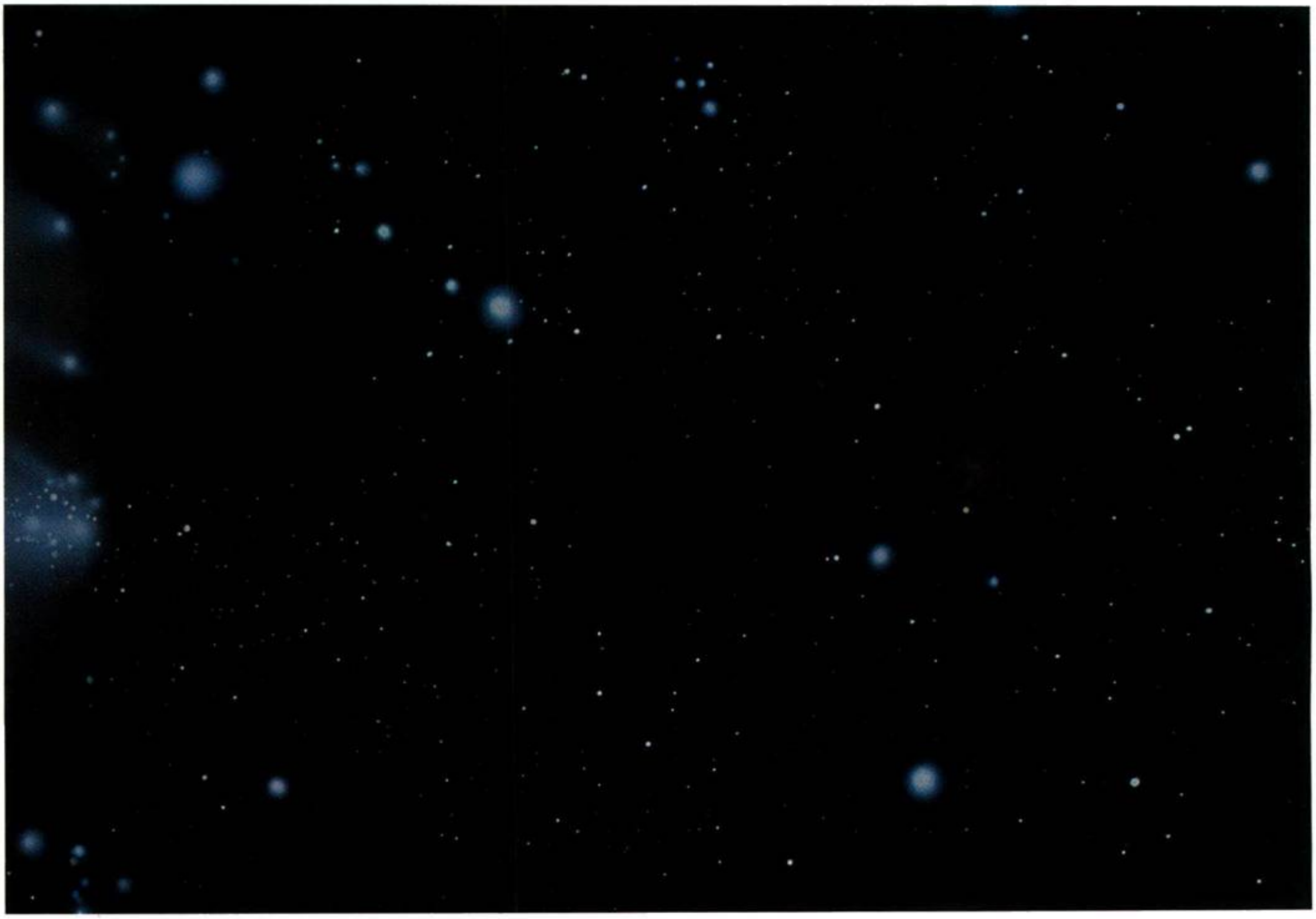
According to the most recent astrometric data from Hipparcos, the galactic center is about 23 thousand light-years away, rather than the older figures of 26 to 28 thousand light-years. Up to about thirty years ago, the galactic center was shrouded in secrecy: huge clouds of dust and gas hide it completely from optical telescopes. But radio, infrared, x-ray, and gamma-ray observations are now allowing astronomers to peek into the center of the galaxy, and have revealed that it is a place of intense radiation, strong "winds," activity, and star formation. Much of the dust in an area several hundred light-years accross radiates strongly in the infrared because it is heated up by a central source.

For many reasons astronomers are almost certain that there is a black hole

Sagittarius A*, **the "monster" at the center of the galaxy, imaged with the orbiting Chandra X-Ray Telescope.**

Chandra X-Ray Observatory





Mark Paternostro

at the center of the galaxy. Its mass is believed to be several million times that of the sun. Astronomers are almost certain that it is located at a pointlike radio object called Sagittarius A* (pronounced A-star), the strongest non-thermal radiation source in the galaxy. Recent high-resolution x-ray images obtained with Chandra are very likely confirming this, says Frederick Baganoff of the MIT Center for Space Research, who leads Chandra's investigation of the galaxy. "For the first time we detected x-ray emission from a point source that coincides with a massive black hole within a few microarc seconds," says Baganoff.

Compared to certain other galaxies, such as Seyfert galaxies or quasars, our galaxy radiates relatively little from its center. The black hole seems to be surrounded by a large number (158) of point-like x-ray sources. "We will be looking to see in subsequent years if some of those point sources disappear, and whether some new ones appear — things that are flaring, either x-ray binaries or stars with corona flares," says Baganoff.

Joseph Lazio of the Naval Research Laboratory in Washington says that radio observations also confirm the existence of a black hole. In fact, they were one of the first indications. Sgr A* was initially observed as a radio source, and it is very likely that the radio waves come from the accretion disk. Since radio interferometers with baselines thousands of miles long have the highest spatial resolution, astronomers hope that soon they will be able to pinpoint exactly where the black hole is.

"There are some existing proposals using interferometric techniques that could actually show the shadow of the black hole on the accretion disk," suggests Lazio. This might be possible if observations are made at very high radio frequencies, around 100 Gigahertz, he suggests.

"If you have high-enough resolution, which interferometric observations may give you in ten years, it may be possible to see the accretion disk with the hole in the middle," claims Lazio. His team has been able to obtain radio images that show long filaments caused by complex magnetic field structures. Electrons radiate synchrotron radiation when spiraling around magnetic field lines. Near Sgr A* radio astronomers discovered long filaments emitting in radio frequencies.

Might brown dwarf stars (barely visible, only through blocking background stars) permeate the galaxy?

They are only observed in the galactic center, in an area within 450 light-years. "They are certainly linked to conditions in the galactic center, and the central black hole plays a role in that," says Lazio. Astronomers believe that high turbulence, a crowded region of massive stars, a fountain of antimatter, and other exotic conditions prevail near the galactic center.

So there we have it — a tour of some of the most unusual and absorbing regions of the galaxy now being studied. These gems will perhaps help to unlock some of the mysteries of the unending life cycles of the stars. **A**

Alexander Hellemans is a science writer living in Naples, Italy.

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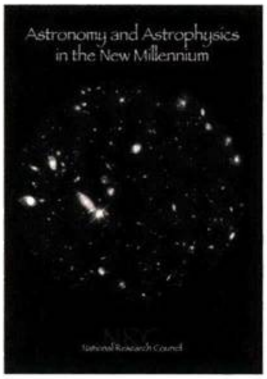
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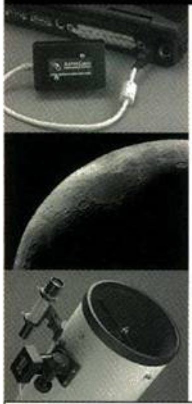

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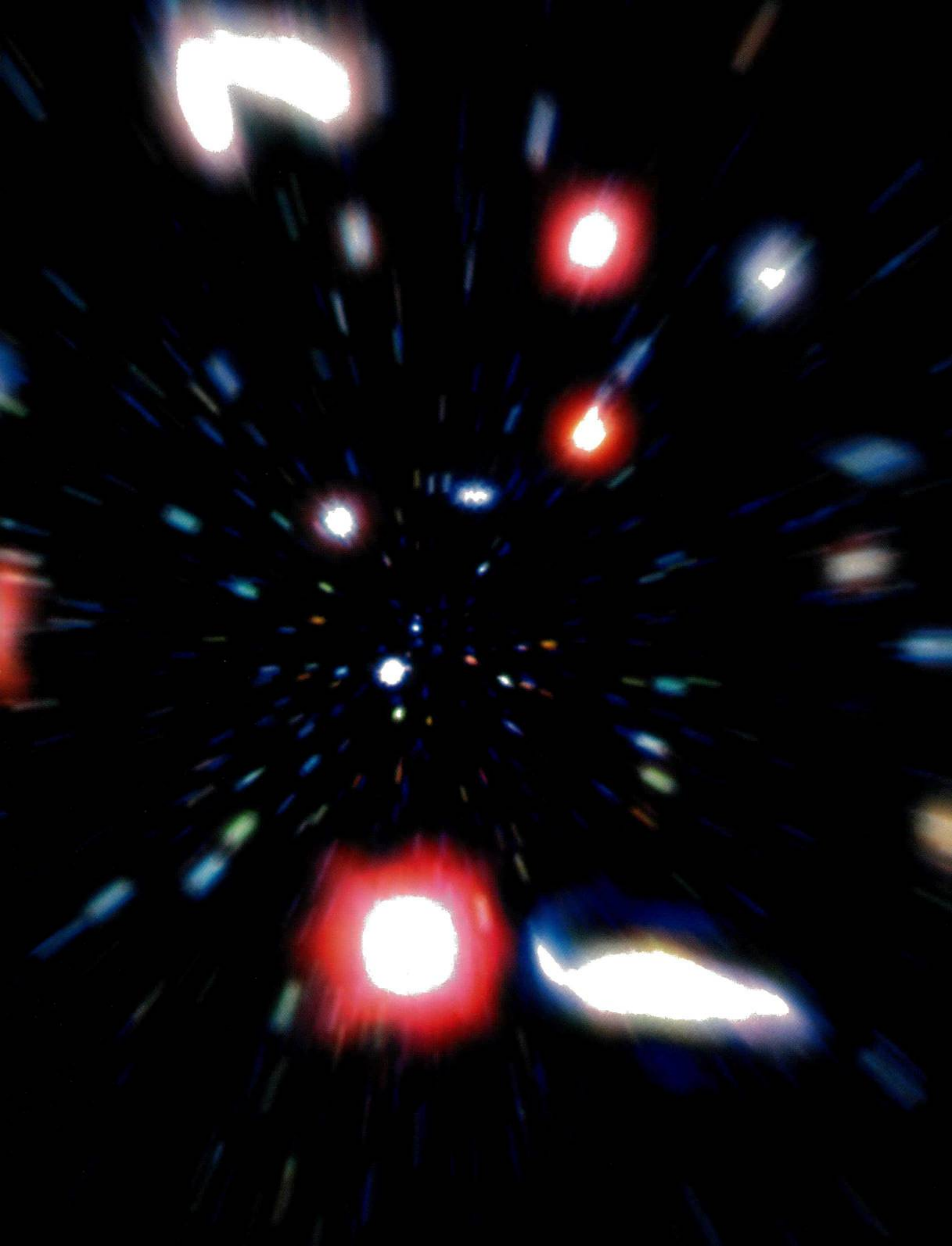
GOING THE DISTANCE

Without knowledge of cosmic distances, the secrets of the universe would remain locked.

by Marcia Bartusiak

Consider the vexation in not knowing with certainty whether you are three-foot-tall or six-foot-tall, or that the distance from Chicago to Los Angeles is 1,000 miles or 2,000 miles. Buying a new pair of slacks or planning this summer's roadtrip would be a guaranteed headache. But believe it or not, astronomers are regularly saddled with such uncertainty when it comes to nailing down some of the most fundamental cosmological parameters.

In the closing decades of the 20th century, astronomers were stalled. The Hubble Constant — a simultaneous measure of the universe's expansion rate, and key to its age and ultimate dimensions — persistently varied by a factor of two among different collaborations. To cosmologists, not knowing such a fundamental feature of the cosmos was, and still is, terribly frustrating.



Through no inherent fault or lack of ingenuity amongst its ranks, astronomy is steeped in a rich tradition of uncertainty when it comes to determining distances to stars, nebulae, and galaxies. Still, despite the difficulty, astronomers have continually devised many clever ways to adequately determine distance, and the good news is that they keep getting better and better.

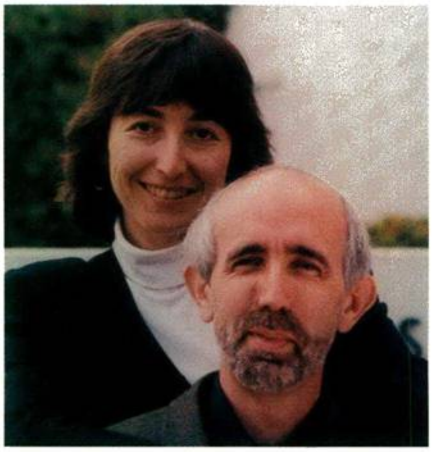
"Twenty years ago there were huge problems," says R. Brent Tully of the University of Hawaii. "We didn't have confidence in our distance measurements to close-by objects such as the Andromeda Galaxy. But now there seems to be a falling-into-place." New detectors, more powerful computers, and new distance markers — coupled with the use of the Hubble Space Telescope (HST) and powerful ground-based observatories — are at last allowing astronomers to conduct precise surveys. "The revolution came about because we now have the technology to implement ideas that were so difficult in the past," adds Saul Perlmutter of the Lawrence Berkeley National Laboratory in California. In the process, long-held notions about the dynamics of the universe have been completely overturned.

BABY STEPS

Astronomical distance measurements outside of the solar system got a serious boost in 1838 when the German astronomer and mathematician Friedrich Wilhelm Bessel successfully measured the distance to the nearby star 61 Cygni (see "Constructing the Distance Ladder," page 28).

Measurements beyond the Milky Way Galaxy became possible in the early 1900s thanks to the work of astronomers like Henrietta Swan Leavitt. While working at the Harvard College Observatory, Leavitt discovered a fascinating property of Cepheids — variable stars that regularly pulsate in size and luminosity over periods of just a few days. She noticed that the period of the pulsation correlates closely with the Cepheid's brightness: the longer the period, the brighter the star.

With a calibrated Cepheid period-luminosity relation, astronomers finally possessed the means to figure out a star's intrinsic luminosity, and ultimately its distance. Cepheid stars could be treated as "standard candles" — well-understood and reliable brightness indicators.



Top: 2.5 million light-years and closing: Cepheids in the arms of Andromeda reveal the proximity of our near neighbor. B.J. Mochejska/FLWO/MDM

Left: Henrietta Swan Leavitt (1868–1921). HCO

Right: Cosmic couple Wendy Freedman and Barry Madore carry the Cepheid torch. Raleigh Souther

An object's brightness decreases with the square of its distance. So, by knowing a Cepheid's intrinsic luminosity, derived from the pulsation period, astronomers are able to determine how far away the star is by seeing how much it appears to have dimmed. Moreover, astronomers have been treated to a bonus. As Cepheids are 10,000 times brighter than the sun, they can be spotted at great distances.

SURVEYING THE EXPANSE

(CEPHEID VARIABLES)

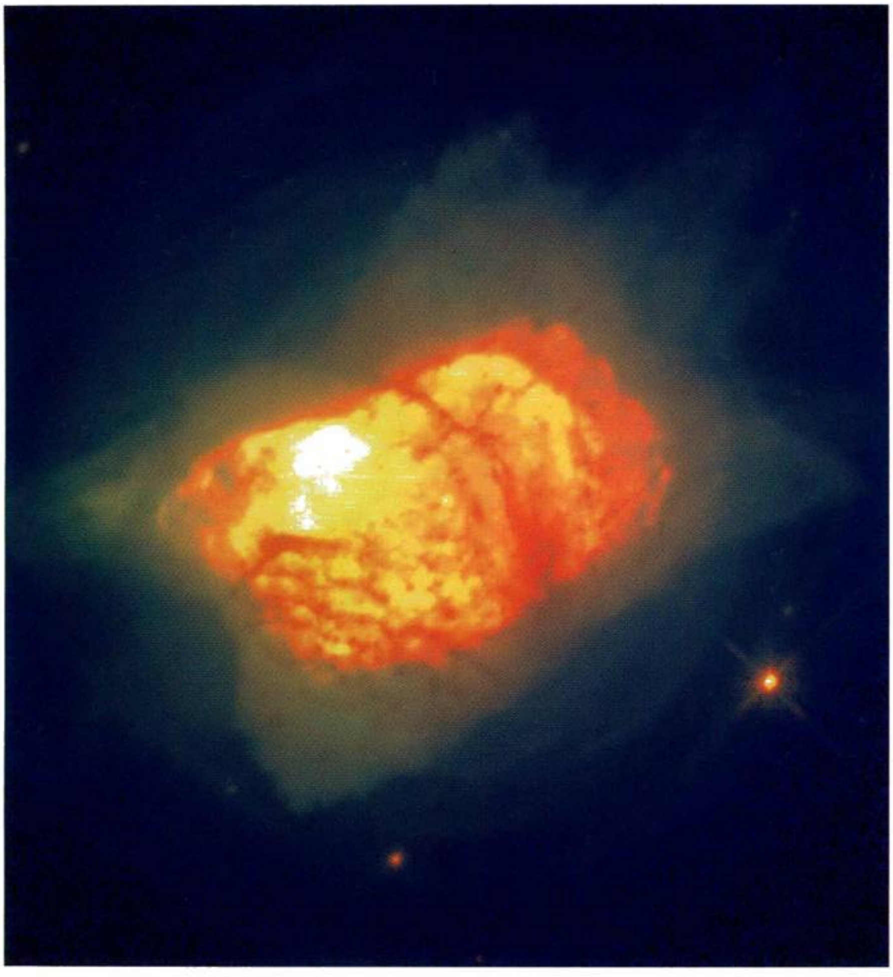
It was observations of Cepheids in M31, the Pinwheel Galaxy in Triangulum (M33), and NGC 6822 that allowed American astronomer Edwin Hubble to discover the universe in 1923. He conclusively proved that these "spiral nebulae" don't reside within the borders of the Milky Way Galaxy. But, rather, they are distant galaxies, comprised of billions of stars, lying millions of light-years away.

Hubble also noticed a pattern in his growing catalog of extragalactic distance measurements: The more distant the galaxy, the more its light shifted toward the red end of the spectrum. He concluded that the light waves were getting stretched (redshifted) because the universe is expanding. The farther away the galaxy, the greater its recessional velocity.

Hubble calculated an expansion rate for the universe (Hubble Constant) of 500 kilometers per second per megaparsec (one parsec is equivalent to 3.26 light-years, and the prefix "mega" means million), but eventually a better understanding of the different types of Cepheid variables brought the rate down to between 50 and 100.

Shifting that expansion rate into reverse, astronomers can extrapolate back to a time when all matter occupied the same space — the moment of the Big Bang. A Hubble Constant ranging from 100 to 50 translates into a universe from 10 to 20 billion years old, respectively. This uncertainty persisted for several decades. What's more, each camp — those defending a low Hubble Constant and those fighting for a higher value — fiercely argued that their methods were better calibrated and thus more precise.

Left: Multiple distance indicators may lie waiting in remote galaxies such as M51. ING/WHT
Below: Planetary nebulae, like the Milky Way's NGC7027, are seen out to the Virgo Cluster. NASA/HST



STEP BY STEP

Settling the disagreement over the Hubble Constant became a high priority in the closing decades of the twentieth century. So much so, in fact, that a chief design constraint for the HST was that its aperture be large enough to significantly extend the Cepheid-based distance scale — all the way out to the Virgo Cluster some 50 million light-years away. The 2.4-meter HST mirror allows astronomers to resolve Cepheids ten times farther than ground-based telescopes. Since 1993, members of the Hubble Key Project, led by Wendy Freedman of the Carnegie Observatories, as well as other users of HST, have discovered hundreds of new Cepheids in more than two dozen galaxies. As a result, the Key Project now calculates a Hubble Constant of 72 kilometers per second per megaparsec, give or take 10 percent — just about in the middle of the previously disputed range.

It was important to find Cepheids in galaxies beyond our Local Group and out to Virgo. Cepheid distance measurements are the workhorse of the cosmological distance determination business. In fact, astronomers use Cepheid-determined distances to calibrate further distance measurements, forming what's known as the Cosmological Distance Ladder (see "Constructing the Distance Ladder," page 28). To everyone's delight (and relief), these various markers are agreeing with one another fairly well out to the Virgo Cluster. "It's nice to see that happen," says Freedman. "The distance ladder isn't so shaky anymore."

COUNTING HEADSTONES

(PLANETARY NEBULAE)

Planetary nebulae — luminous death shrouds of low-mass stars like the sun — form an additional rung on the distance ladder. As these low-mass stars evolve from their hydrogen-burning phase and on to the red giant phase, they eventually shed their outer layers of gas into interstellar space, leaving behind an incredibly dense and hot white dwarf core. The sloughed gas subsequently absorbs ultraviolet radiation from the hot stellar remnant and largely re-emits it at a few choice wavelengths, especially a strong green line formed by twice-ionized oxygen atoms. This makes planetary nebulae out to the Virgo Cluster easy to spot with ground-based telescopes.

Planetary nebulae are valuable distance indicators because they are found not only in spirals but also in elliptical galaxies, which don't contain Cepheids. Thus, they can bridge distance scales based solely on one type of galaxy or the other, notes Robin Ciardullo of Pennsylvania State University, who, along with George Jacoby of the Kitt Peak National Observatory, largely pioneered this technique.

In the late 1980s, Jacoby and Ciardullo used planetary nebulae to measure a distance to the Virgo Cluster. Others, who gauge distances based on the surface brightness of elliptical galaxies, a technique introduced by University of Hawaii astronomer John Tonry, seem to agree. "Despite the fact that our techniques have nothing in common, we get the same answer," notes Ciardullo. Follow-up investigations by the Hubble Cepheid team also match their findings within 10 percent.

BRIGHTER, FASTER, FARTHER?

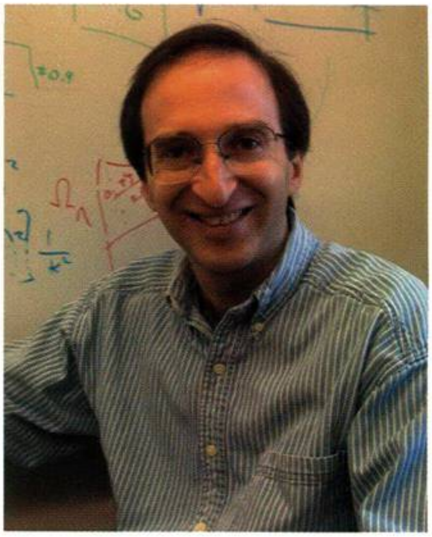
(TULLY-FISHER RELATION)

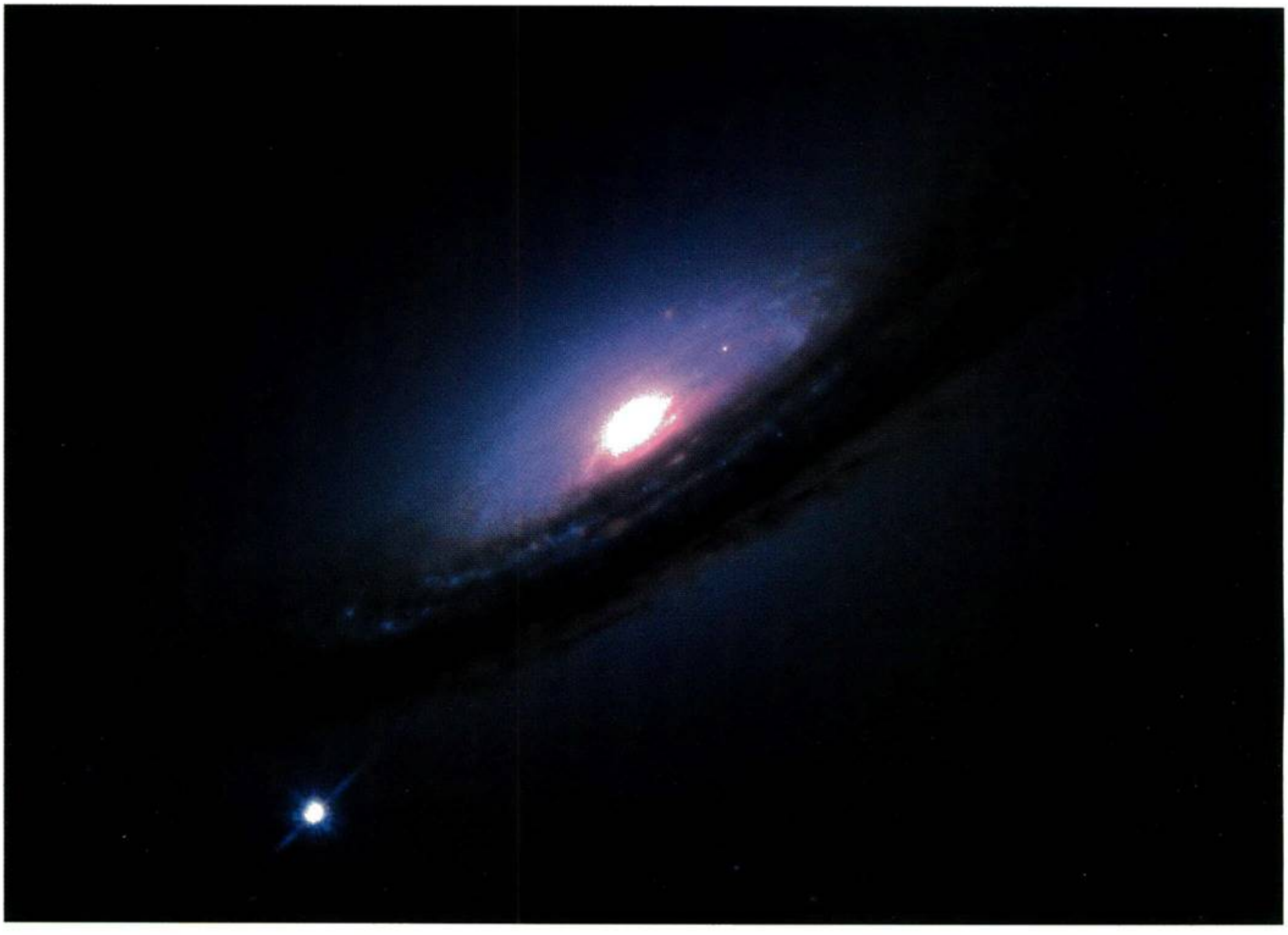
Continuing up the ladder, previous methods are used to calibrate techniques, such as the Tully-Fisher relation, which allows astronomers to measure distances even greater than that of the Virgo Cluster. In the mid-1970s, astronomers R. Brent Tully, now with the University of Hawaii, and J. Richard Fisher of the National Radio Astronomy Observatory, discovered a link between a spiral galaxy's luminosity and its rotation rate.

Bright spiral galaxies, having more mass, rotate faster than dimmer spirals. By determining a galaxy's rotation rate — one way is to measure hydrogen emissions with radio telescopes — astronomers are able to peg its intrinsic luminosity and ultimately use it as a standard candle.

The Tully-Fisher relation is valuable because it's so handy. With other methods, such as planetary nebulae or Cepheids, astronomers must hunt for specific objects that may or may not be found. The most recognizable galaxy type in the cosmos — the ubiquitous spiral — can be found anywhere they look. The method does have larger margins of uncertainty, but it serves as a useful double-check. Tully and his colleagues have analyzed nearly a thousand galaxies in this way, out to about one hundred million light-years.

Right: Supernova sleuth Saul Perlmutter waited ten years for his team to finally hit pay dirt. LBNL
Below: Modern supernovae searches routinely uncover dozens of blasts, like SN1994D (lower left of image), each year. NASA/HST/High-Z SN Search





SUPER-STANDARD CANDLES
(TYPE IA SUPERNOVAE)

In the last five years, perhaps the most exciting development in cosmic distance measurements has been the use of Type Ia supernovae as standard candles. "This is a revolutionary old method," quips Perlmutter. Walter Baade first suggested in 1927 that supernovae (what he then called "Hauptnovae" or chief novae) would be useful distance markers, but it took many years for astronomers to recognize that there were different kinds of supernovae with differing brightnesses.

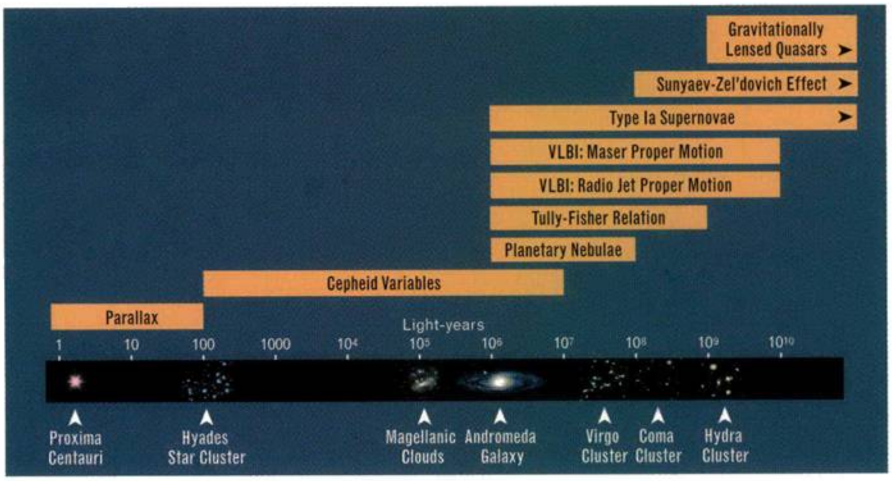
Massive stars blow up as brilliant supernovae (known as "Type II" explosions) when they run out of fuel. Still, there are other ways for stars to go supernova. White dwarf stars, objects as tiny as Earth yet as massive as the sun, often reside in binary star systems and are known to steal gas from their stellar companions.

As a white dwarf pilfers mass, it gets compressed under the weight of the added material. If squeezed down far enough — or to the point that the total mass of the white dwarf reaches about 1.4 times the mass of the sun — a runaway thermonuclear explosion ensues and the entire star is consumed in about a second.

Perhaps most exciting to cosmologists, however, is that such explosions (called Type Ia supernovae) yield a similar peak brightness, allowing them to be calibrated as standard candles. And they are so bright — up to 10 times brighter than Type II supernovae — that they can be seen all the way to the edge of the visible universe.

Perlmutter started working on this approach a decade ago, in part to prove that supernovae could be reliably spotted and in appreciable numbers. He and his colleagues formed the Supernova Cosmology Project and by the mid-1990s were finding batches of supernovae with every observing session, convincing major observatories that it was worthwhile to schedule telescope time to examine these objects as distance markers.

Meanwhile, another international group of astronomers, known as the High-Z Supernova Search Team, had long been focusing on understanding the mechanisms of these explosions. "We complemented each other," notes University of California — Berkeley astronomer Alex Filippenko, who has worked on both teams.



The rival teams observe many fields on the celestial sky once or twice a year, right after a new moon when the sky is darkest, using telescopes in Chile and Hawaii. Three weeks later, they examine the same fields to detect changes. Type Ia supernovae are extremely rare, but by examining hundreds of thousands of galaxies at a time, a dozen or so supernovae are usually sighted in any one session. They then follow up with a variety of ground-based telescopes to examine the candidates in more detail.

In 1997, preliminary results indicated that some of these supernovae, a few billion light-years distant, appeared fainter than expected. They thought that perhaps supernovae in the past were less luminous because of differing chemical compositions. But, since the spectra of the distant supernovae did not differ from stellar explosions nearby, the supernova hunters concluded that it's more likely the universe was expanding more slowly in the past and is now accelerating. This would make the supernovae more distant (and dimmer) than expected.

The recent discovery of the most distant Type Ia supernova ever observed, by Adam Reiss of the Space Telescope Science Institute and Peter Nugent at the Lawrence Berkeley National Laboratory (see AstroNews July 2001, page 20), corroborates the finding of an accelerating universe. It now seems highly probable that the universe is dominated by a yet-unknown form of dark energy, which usurps the gravitational attraction between matter in the universe to speed up the cosmic expansion.

Upon initially hearing the news, Tully had confidence in the accelerated expansion hypothesis, mainly because the new finding settles some old disputes. Previously, when distance measurements suggested a high Hubble Constant, problems arose. That's because a large Hubble Constant implies that the universe is fairly young, generally 10 billion years or less.

But certain stars in the Milky Way Galaxy have been found to be far older than 10 billion years. With an added dark energy to gradually boost expansion over time, the universe suddenly becomes older. "There is no longer a conflict," says Tully. "Everything works much better."

Nonetheless, astronomers like Perlmutter are still proceeding with caution. "What will help," he says, "is going out into space to measure thousands of supernovae each year." And the SNAP (Supernova/Acceleration Probe) satellite is on the drawing board to do just that.

With SNAP, astronomers will be able to measure the universe's expansion at various epochs to see how it has changed over time, and determine what's causing the current acceleration.

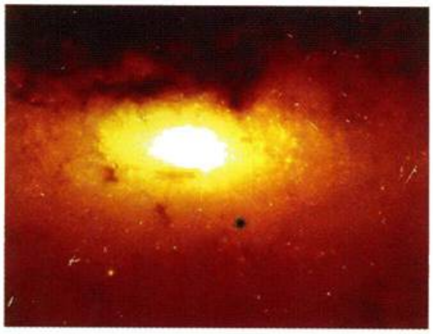
AVOIDING THE LADDER ALTOGETHER
(VLBI)

Astronomers over the last decade have also been developing and enhancing new techniques that will allow them to skip the distance ladder altogether, to take distance measurements of faraway objects directly.

Using the Very Long Baseline Array (VLBA) — a set of ten radio telescopes situated around the world from Hawaii to the Virgin Islands — astronomer James Moran of the Harvard-Smithsonian Center for Astrophysics and his colleagues recently made a direct distance measurement to the spiral galaxy NGC 4258 (M106).

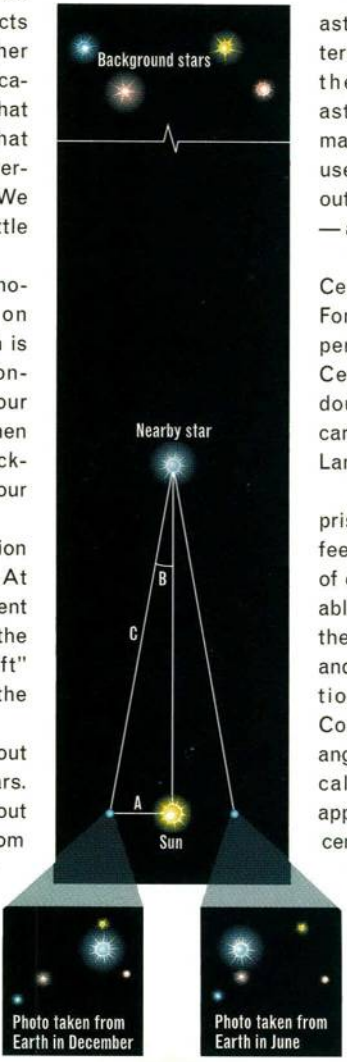
With the radio telescopes acting as one giant dish, thousands of miles wide, they were able to tightly focus on the galaxy's core and measure the velocity of water masers — compact molecular clouds that emit an intense radio signal — swirling in a disk of gas at the galaxy's center. Comparing the masers' intrinsic speed (inferred from Doppler shift of the maser emission) with how fast they appear to be moving as seen from Earth yielded a distance. (Imagine a boat, racing across the far horizon at a known speed. Seeing how much more slowly the boat appears to move from shore gives one a means of determining its distance with a bit of geometry.) In this way, M106 was found to be nearly 24 million light-years away.

"[M106] was the miracle source," says Moran. "There was perfect placement of the masers within the disk." Astronomers using HST to measure Cepheids in M106 initially came up with a slightly longer distance, about 26 million light-years, but recent corrections to the HST data bring them closer to the maser-based distance. "We like to look upon the masers as giving the fundamentally correct answer, as it's based on simple geometry," says Moran.



Deep in the dusty core of M106, swirling masers act as cosmic beacons. NASA/HST

CONSTRUCTING THE DISTANCE LADDER: LOCAL DISTANCE MEASUREMENTS


Background stars
Nearby star
B
C
A
Sun
Photo taken from Earth in December
Photo taken from Earth in June

Measuring astronomical distances has never been a one-shot deal. Observers have proceeded slowly, step by step, along a distance ladder. Nearby objects, with well-known properties, are used to calibrate brighter objects that can be used as distance indicators farther out. They in turn are used to calibrate other indicators to even greater distances. One error in that chain affects the accuracy of all the steps that follow. "There's always a weak point," says University of Hawaii astronomer R. Brent Tully. "We charge after the weak point of the moment, settle it, and then something else steps in."

The first (and most reliable) step is trigonometric parallax, which depends solely on geometry and the radius of Earth's orbit, which is very well known. The concept is easily demonstrated by holding a finger six inches from your eyes. Looking at your finger first with one eye, then the other, it appears to shift against the background. You'll notice that the shift lessens as your finger moves farther away.

Earth shifts every six months some 186 million miles from one side of its orbit to the other. At each extreme, astronomers get a slightly different line of sight to a nearby star, as seen against the distant background stars. This "parallax shift" allows observers to triangulate and measure the distance to the star (see diagram).

Modern parallax measurements are useful out to several hundred light-years for individual stars. Friedrich Wilhelm Bessel was the first to carry out such a stellar parallax measurement in 1838 from his observatory in Königsberg, Prussia (now Kaliningrad, Russia). He measured the shift for the star 61 Cygni, obtaining a distance of 10.4 light-years (very close to today's accepted value of 11.4 light-years).

Before 1989, only a few dozen stars had parallax measurements with 5 percent error or less. It was then that the European Space Agency's Hipparcos satellite began a four-year mission to measure the shift for more than 7,000 stars to 5 percent accuracy. With lesser accuracy, it pegged the parallaxes and brightness of more than a million stars in the Milky Way.

For stars beyond the reach of parallax, astronomers turn to other techniques. Star clusters, for example, offer a good collection of stars at the same distance. By studying clusters, astronomers can gain a handle on the absolute magnitude of a certain spectral type. They can then use that class of stars as a standard candle farther out. This can be done out to the Magellanic Clouds — about 150,000 light-years.

The premiere standard candles are the Cepheids, supergiant stars that regularly pulsate. For a century, astronomers have known that the period of the pulsation is directly related to the Cepheid's intrinsic luminosity. But a valuable double-check on that relationship was recently carried out by Caltech graduate student Benjamin Lane and his collaborators.

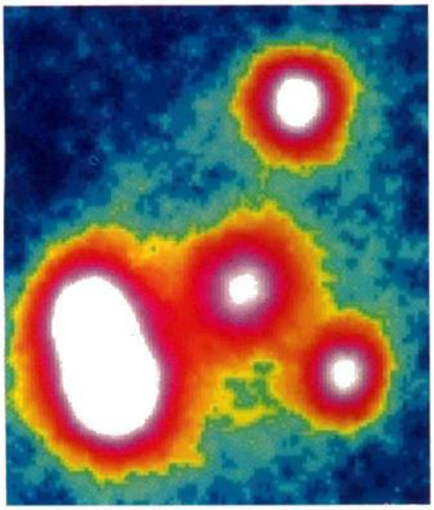
The Palomar Testbed Interferometer is comprised of two 16-inch telescopes, separated by 360 feet, that conspire to generate the resolving power of one giant telescope. The twin instruments were able to resolve the disk of Zeta Geminorum, one of the brightest Cepheids in the northern sky. Lane and his team could then observe the star's pulsation and measure the change in its diameter. Comparing this modulation with the corresponding angular change on the sky, the astronomers could calculate the distance directly, which came to approximately 1,100 light-years (give or take 15 percent). With improvements, they hope to better the accuracy to within a few percent. Lane's work serves as a valuable calibration on the luminosity of Cepheids farther out, independent of Leavitt's period-luminosity law.

Other variable stars are useful in a similar way. Yellow RR Lyrae stars, for example, have very short periods (less than a day) and seem to have the same absolute magnitude. Spotting an RR Lyrae thus gives you a handle on the distance required to reach its level of dimness. — M.B.

KEEPING THINGS PROPER

(QUASAR JETS)

Along a similar vein, radio jets shooting out from the cores of active galaxies may reveal their distances. Roughly ten percent of quasars and active galaxies have active jets, so there's a good supply of sources for this technique. More importantly, they can be measured to distances far beyond those currently reached by Cepheids or supernovae. Following jet motions with radio telescopes, observers compare apparent motion to actual motion, based on Doppler shift and magnetic field measurements.



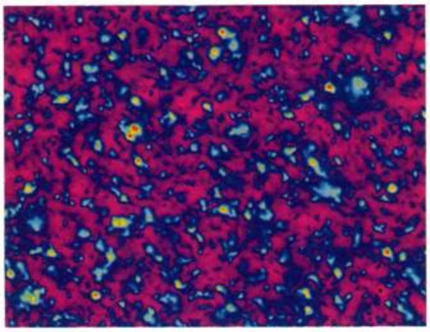
Dan Homan and John Wardle of Brandeis University conducted such a test on the quasar 3C 279. The movement of any one feature in the jet is on the order of a few milliarcseconds on the sky. "That's about the height of a fairly tall person on the moon as seen from Earth," notes Homan. But, as with the masers, radio astronomers can detect such subtle motions with the VLBA. With this direct tape measure, Homan and Wardle arrived at a distance to 3C 279 of about 6 billion light-years. The Hubble Constant they calculate from this information is consistent with an accelerating universe deduced from the supernovae findings.

COSMIC SPECTACLES

(GRAVITATIONAL LENSING)

Another direct-measurement technique that shows great promise is gravitational lensing. Light from a distant source, such as a brilliant quasar, can often be deflected and split by the gravitational field of an intervening object, such as a galaxy or cluster of galaxies. In other words, the galaxy acts as a lens. As a result, multiple images of the quasar are detected by observers. With the light beams taking different paths around the galaxy, each traverses a different distance in its journey to Earth. If the distant source briefly flares, each image will reveal it at different times, the first flare arriving along the beam with the shortest path, followed by the longer paths. By modeling the size and mass of the gravitational lens, astronomers can determine its distance directly.

Astronomers have timed such flare delays in several lensed quasars, but it has taken months and even years to monitor the changes in the multiple images. Princeton astrophysicist Edwin Turner and his associates, for example, monitored the flaring of the double quasar 0957+561 for more than a year. One image dropped in brightness by about 15 percent; 417 days later, its twin image diminished in the same way. From this, they calculated a Hubble Constant of 64 kilometers per second per megaparsec.



Left: A nearby galaxy, lying seven billion light-years in front of PG1115+080, creates multiple images of the quasar. NOAJ/Subaru **Above: Simulated galaxy clusters (red clumps) modify existing temperature differences in the microwave background.** J. Burwell/U. Pen/U. Seljak

Recently, astronomers George Chartas of Penn State and Marshall Bautz of MIT noted a dramatic fluctuation in a lensed quasar over just a few hours in x rays, using the Chandra X-Ray Observatory. More sightings like this open up the possibility of using this technique with better efficiency.

NEW KID ON THE BLOCK?

(SUNYAEV-ZEL'DOVICH EFFECT)

There is renewed interest in a technique based on the Sunyaev-Zel'dovich effect, named after the Russian physicists Rashid Sunyaev and Yakov Zel'dovich, who first discussed it some 30 years ago. They pointed out that the cosmic microwave background, the remnant radiation released shortly after the Big Bang, can be scattered by intervening matter, such as huge clusters of galaxies.

At low radio frequencies, the temperature of the microwave background near the cluster appears lower. At higher frequencies, the background appears brighter, because the hot electrons in the cluster scatter the microwave photons and boost their energy. By studying background changes, along with the cluster's x-ray properties, one can assess the thickness of the cluster and, hence, its overall size. Comparing actual size with the cluster's apparent size on the sky, the cluster's distance can be determined.

John Carlstrom at the University of Chicago and several colleagues have been studying clusters in this manner with both x-ray space telescopes and millimeter radio arrays in California. So far, they've determined distances to some 17 clusters, out to several billion light-years. "For now, the Sunyaev-Zel'dovich effect is more like an independent check rather than leading the way, but I think that its future looks very, very good," says Carlstrom.

BRINGING IT HOME

Astronomers have never claimed immunity from Murphy's Law. As remote distance measurements are agreeing nicely, one of the primary rungs of the distance ladder has recently been plagued with problems. "The biggest uncertainties are in our own backyard," warns Freedman.

For unknown reasons, the distance to the Large Magellanic Cloud, stubbornly varies among different indicators. Parallax measurements of Cepheids yield a distance of about 180,000 light-years, while other methods, like the use of RR Lyrae stars (see "Constructing the Distance Ladder," page 28) and eclipsing binaries, suggest shorter distances, from 140,000 to 150,000 light-years.

"No distance measurement technique is completely fail-safe, " says Filippenko. "But the hope is that together we can be consistent."

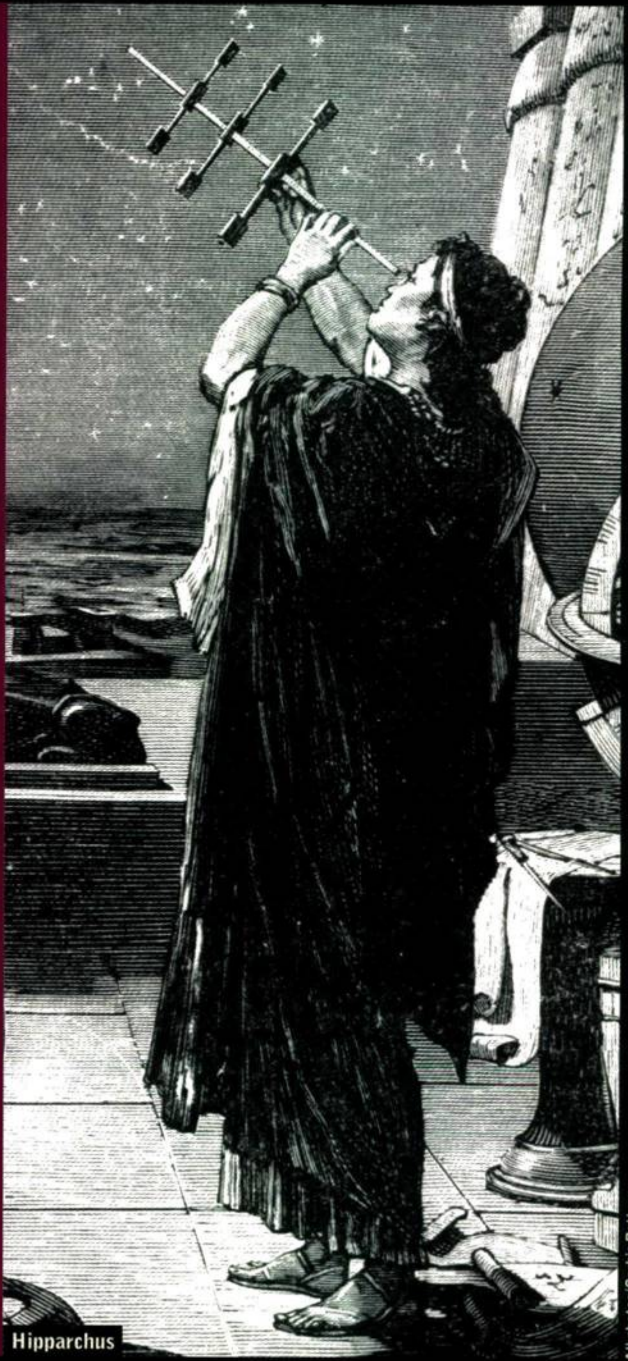
Marcia Bartusiak is a member of Astronomy's *editorial advisory board. Her latest book is* Einstein's Unfinished Symphony: Listening to the Sounds of Space-Time *(Joseph Henry Press, 2000).*

At the Head of their Class

The top 25 astronomers of all time defined our view of the cosmos.

by Kelly Kizer Whitt

Who were the greatest astronomical minds of the past millennium? Newton deciphered gravity and Einstein reworked it with relativity, giving humans their basic views of science and the cosmos. But 23 other intrepid thinkers helped astronomy make quantum leaps, reaching new heights of understanding and discovery. Here is our short list of astronomical geniuses, but if you think someone was left out who should have been included, we're open to suggestions! E-mail us at: Top25@astronomy.com.



Hipparchus

All photos/Corbis Bettman

1 Aristarchus of Samos
ca. 310–230 B.C.

This celebrated Greek mathematician and astronomer was the first person to propose a sun-centered, or heliocentric, universe. This idea incorporated Aristarchus's attempts to determine the sizes and distances of the sun and moon. He advocated a large sun that was farther from Earth than the moon, and he set the stars on a sphere at a great distance from the sun. He also tried to measure the distances to the sun and moon.

2 Eratosthenes
276–194 B.C.

A Greek scholar who found success in many subjects, Eratosthenes set a milestone by calculating Earth's circumference. He accomplished this feat mathematically by comparing shadows in Syene and Alexandria and measuring the distance between the two. He also measured, with surprising accuracy, the tilt of Earth's axis and the distance to the sun and moon.

3 Hipparchus
190–120 B.C.

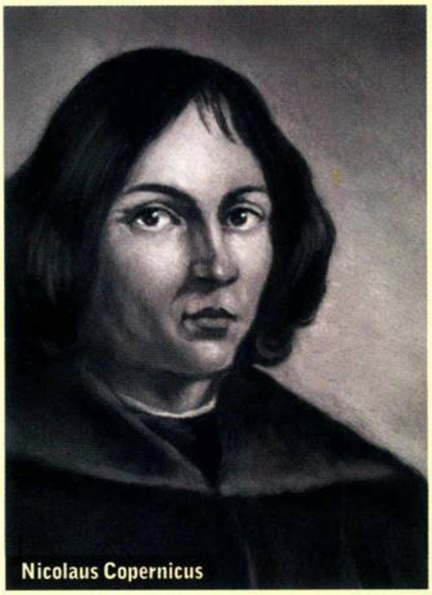
The Greek Hipparchus of Rhodes compiled the first known catalog of stars and created the first map of the sky. He organized the stars by constellation and devised the magnitude system. Hipparchus also made accurate measurements of the precession of the equinoxes, the moon's distance, and the length of the year, and he may even have invented the astrolabe. Unfortunately, the works of Hipparchus are recorded second-hand: the original scrolls were lost.

4 Ptolemy
ca. A.D. 87–150

The Greek "prince of astronomers," Claudius Ptolemaeus of Alexandria was a proponent of a geocentric, or Earth-centered, model of the universe. Although later proved incorrect, his so-called Ptolemaic system reigned for 1,500 years. His celebrated star catalog, the *Almagest*, expanded the work of Hipparchus and Plato, and also included other resources he uncovered from the scrolls of the Great Library of Alexandria; sadly, the library later burned.

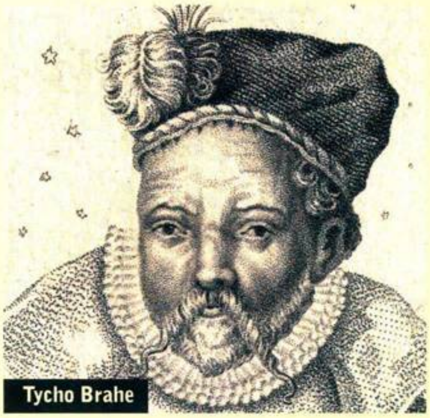
5 Nicolaus Copernicus
1473–1543

The Polish astronomer Mikolaj Kopernik broke the thousand-plus-year dry spell in astronomy by finally producing a work, *De Revolutionibus Orbium Coelestium*, in 1543, which outlined a heliocentric model of the solar system that eventually unseated the long-standing Ptolemaic system. Withholding it from publication until the end of his life (due to church opposition), Copernicus sparked a revolution of enlightenment that lasted through the work of Newton, nearly two centuries later.


Nicolaus Copernicus

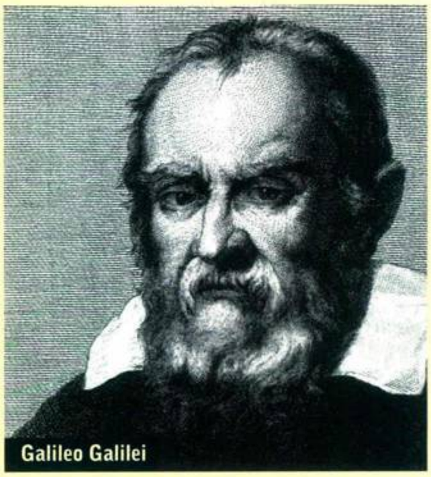
6 Tycho Brahe
1546–1601

A colorful character (he had his nose cut off in a duel and fashioned a new one from wax and gold), this Danish observer may have been the greatest of the pre-telescopic era. Tycho made extremely accurate observations of the nova of 1572 and a comet in 1577, concluding that the comet was not in Earth's atmosphere but farther out in space. His observatory, Uraniborg, on the island of Hven, served as a catalyst for other great astronomers, including Johannes Kepler. Tycho believed the sun orbited Earth but that other planets orbited the sun.


Tycho Brahe

7 Galileo Galilei
1564–1642

Italian-born Galileo will forever be celebrated as the first to turn a telescope skyward, opening a whole new phase of astronomy. Working at Pisa, Padua, and Florence, he published *Sidereus Nuncius* (*The Starry Messenger*), outlining his discoveries, which included mountains on the moon, the starry nature of the Milky Way, and the phases of Mars. He discovered the phases of Venus and was the first to observe the four brightest jovian satellites, which legitimized the Copernican (heliocentric) system. His observations and assertions over the sun-centered solar system led him to be convicted of heresy by the Roman Catholic Church, and he was imprisoned at Arcetri during his last years.

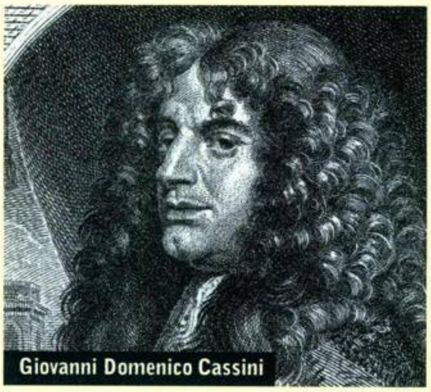

Galileo Galilei

8 Johannes Kepler
1571–1630

An assistant of Brahe's, the German Kepler used his former employer's observations to postulate elliptical orbits for the planets and describe their movements in his three Laws of Planetary Motion. In 1604, he observed a supernova in Ophiuchus that was later named Kepler's Star. Kepler produced five important treatises on astronomy, including *Epitome Astronomiae Copernicanae.*

9 Giovanni Domenico Cassini
1625–1712

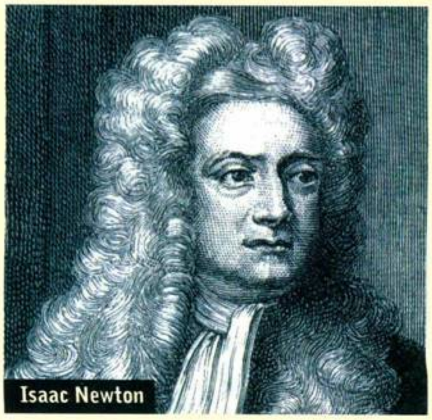
Italian-born Cassini first served as a professor of astronomy at Bologna before moving to France as director of the Paris Observatory. His son, grandson, and great grandson all held the position in succession. Cassini discovered four of Saturn's moons (Tethys, Dione, Rhea, and Iapetus) and the dark gap in the planet's rings that was named the Cassini Division. He also measured the rotation periods of Mars and Jupiter and refined the distance to the sun.


Giovanni Domenico Cassini

10 Isaac Newton

1642–1727

The father of modern science, Sir Isaac was probably the greatest of all astronomers. As Lucasian professor at Cambridge University, he formulated the basic understanding of the universe and its mechanics with his pioneering studies of gravitation and his three Laws of Motion. He discovered that sunlight can be separated into different colors of light. In 1668, Newton made the first reflecting telescope, which is now commonly referred to as the Newtonian. Later, in 1687, he published *Philosophiae Naturalis Principia Mathematica*, his magnum opus explaining the mechanics of the solar system and one of the greatest efforts by a single person in world history. Newton also served as Master of the Mint and sat in Parliament.


Isaac Newton

11 Charles Messier

1730–1817

The French comet hunter discovered 13 comets independently and codiscovered a half-dozen others. While hunting for comets, Messier compiled a list of fuzzy objects that were not comets in order to avoid them. These catalog entries were later identified as star clusters, nebulae, and galaxies, and became the *Messier Catalog*. Published in various versions beginning in 1771, the catalog grew to 103 objects by 1781.

12 William Herschel

1738–1822

Born in Hanover, Sir Friedrich Wilhelm Herschel was probably the greatest astronomical observer in history. An amateur astronomer and musician by trade, Herschel spent most of his life in England, settling in Bath. From his garden, he discovered the seventh planet, Uranus, in 1781. The resulting fame led to his appointment as the king's astronomer. Through his observations, Herschel discovered infrared radiation and the largest moons of Uranus and Saturn, cataloged thousands of deep-sky objects, and deduced that the galaxy is a plane that incorporates the sun and that the sun moves within it. Herschel's sister Caroline aided him at the telescope and discovered eight comets of her own.

13 John Frederick William Herschel

1792–1871

William Herschel's son continued his father's work, surveying double stars, nebulae, and clusters. He traveled to the Cape of Good Hope in 1834 to observe Southern Hemisphere objects, becoming the first astronomer to extensively catalog them. The Herschels produced several lists of their discoveries; by 1864 the *General Catalogue* (*GC*) included 5,096 of their objects, and would be revised and extended in 1888 by John L. E. Dreyer as the *New General Catalogue* (*NGC*), containing 7,840 objects. Herschel also made one of the first measurements of the solar constant and did pioneering work in photography, coining the terms "positive" and "negative."

14 Heinrich Ludwig D'Arrest

1822–1875

Along with Johann Galle, this German astronomer co-discovered Neptune in 1846. He suggested comparing Urbain J. J. Le Verrier's predictions with a recently made star chart, and the eighth planet was discovered the same evening. D'Arrest also discovered several comets, published a book on asteroids, and studied nebulae, producing refinements of their positions and discovering 500 new nebulae.

15 Edward Emerson Barnard

1857–1923

A prolific American astronomer, the Nashville-born observer is often remembered as the last great visual observer. Barnard discovered the fifth jovian moon, Amalthea, in 1892. He discovered 16 comets, including the first one discovered photographically, and in 1916 he located Barnard's Star, the fourth-closest star to the sun after the Alpha Centauri system. He identified Barnard's Loop, a swath of ionized hydrogen surrounding Orion, and discovered Barnard's Galaxy in Sagittarius. Additionally, Barnard published a catalog of star-poor regions of the Milky Way; these regions are now known as dark nebulae and bear Barnard designations.

16 George Ellery Hale

1868–1938

A pioneering solar astronomer, Hale invented the spectroheliograph, recognized that sunspots were cooler than the photosphere and had strong magnetic fields, and discovered that the sun's magnetic field reversed polarity with each cycle. Hale was instrumental in the building of three of the world's largest telescopes: the 40-inch refractor at Yerkes, the 100-inch Hooker telescope at Mount Wilson, and the 200-inch reflector (later named the Hale Telescope) at Palomar Mountain Observatory.

17 Henry Norris Russell

1877–1957

A noted American astronomer and theorist, Russell served as director of the Princeton Observatory. In 1928, he studied the spectrum of the sun to determine its composition, and from these results concluded that all stars contain a large amount of hydrogen. He uncovered the relationship between a star's temperature/color and its luminosity, creating a relationship that explained the evolutionary lives of stars that would later be shown in the

Hertzsprung-Russell Diagram. Russell also calculated the masses of binary stars.

Albert Einstein

18 Albert Einstein
1879–1955

Einstein developed the Special Theory of Relativity (in 1905) and General Theory of Relativity (1915–1917), which revolutionzed astronomy and cosmology and defined much of how the universe works. He uncovered the relationship between mass and energy ($E=mc^2$), which explains energy generation in stars, and the relationship between gravity and mass, which causes light to be bent a la Einstein's Ring and Cross. He also found the reasons for idiosyncrasies in Mercury's orbit, eliminating the need for a planet Vulcan. As a German Jew, Einstein fled the Nazis and settled in Princeton, New Jersey in 1933, spending the rest of his life at the Institute for Advanced Studies.

19 Arthur Eddington
1882–1945

Building on the work of Einstein, Sir Arthur's tenure at Cambridge University included deciphering how stars internally generate energy. During the 1919 total solar eclipse, he obtained the observational proof that gravity bends light. In 1924, Eddington devised the mass-luminosity relationship of stars on the main sequence. He was also a highly effective popularizer of astronomy.

20 Harlow Shapley
1885–1972

This American student of Henry Norris Russell became the director of Harvard College Observatory. Shapley made the first accurate estimate of the Milky Way's size and our location in it by studying globular star clusters. He debated Heber Doust Curtis in 1920 over the nature of "spiral nebulae," erroneously asserting that they are within the Milky Way, but he redeemed himself in 1932 when he published the Shapley-Ames catalog of 1,249 galaxies. The catalog showed that galaxies were distributed in gaps and clusters, one of which was named the Shapley Concentration, or Supercluster.

21 Edwin Hubble
1889–1953

A former army officer and boxer, Hubble turned the astronomy world upside-down when in the early 1920s he exploded the distance scale of the universe. Using the 100-inch Hooker telescope at Mt. Wilson, Hubble studied Cepheid variables to reveal that "spiral nebulae" are really separate galaxies at extreme distances. He found that galaxies' redshifts, by which their distances can be determined, also revealed the universe is expanding. Hubble's law states that galaxies recede with a speed that increases with distance.

Edwin Hubble

22 Georges Lemaître
1894–1966

Following Hubble's lead, this Belgian priest and professor at Louvain University modeled the expanding universe using mass, gravity, and the curvature of space. With the help of quantum theory, in 1927 he was able to support his idea of the universe's origin from a "cosmic egg," which later, aided by the ideas of George Gamow, evolved into the Big Bang Theory.

23 Gerard Kuiper
1905–1973

In the early 1950s, the Dutch-American Kuiper formulated, along with Kenneth P. Edgeworth, the existence of icy objects in a belt beyond Neptune that could be a source for short period comets. He discovered Miranda around Uranus and Nereid around Neptune. He also found methane in both these planets' atmospheres and also in Titan's spectrum, making it the first known moon with an atmosphere.

Subrahmanyan Chandrasekhar

24 Subrahmanyan Chandrasekhar
1910–1995

This Indian-American studied stellar physics and black holes at the University of Chicago. He defined the relationship between a star's mass and its fate: Stellar remnants with more than 1.4 solar masses (the Chandrasekhar limit) will collapse into neutron stars or black holes. He also postulated the structures and mass limits of white dwarf stars.

25 Stephen Hawking
1942–

The only living astronomer on our list, this British intellect (who holds the same chair at Cambridge University once claimed by Isaac Newton) studies singularities in the Big Bang, spacetime, and black holes. He proposed that radiation (now known as Hawking radiation) emanates from black holes. His 1998 book, *A Brief History of Time*, sold more copies worldwide than any other book on science in history.

A former copy editor of Astronomy, *Kelly Kizer Whitt is a freelance writer and editor.*

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HIGHLIGHTS OF THE NEXT 25 YEARS

Astronomy *looks forward to the best sky events of the coming decades.*

by Richard Talcott

The next 25 years offer a bevy of wonderful events: eclipses, transits, conjunctions, and more. To whet the appetite of observers around the globe, we've taken a look ahead and selected the best of these events from now through 2026. The clockwork precision of the solar system lets us accurately predict most of these without resorting to a crystal ball. But keep in mind that a similar list compiled 25 years ago would have missed grand comets like Hale-Bopp and Hyakutake, another comet that smashed into Jupiter for all the world to see, and an exploding star in the Large Magellanic Cloud that lit up the southern sky for months. So don't view this as the final word — remember that other events await those who keep their eye to the sky.

2002

May 5	Evening conjunction of Venus, Mars, and Jupiter
May 10	Close conjunction between Venus and Mars
June 10	Annular solar eclipse (Pacific Ocean)
December 4	Total solar eclipse (southern Africa, Australia)

2003

May 7	Transit of Mercury (Europe, Africa, Asia)
May 15/16	Total lunar eclipse (North and South America)
August 27	Very close approach of Mars
November 8/9	Total lunar eclipse (Americas, Europe, Africa)

2004

May 4	Total lunar eclipse (Asia, Africa)
June 8	Transit of Venus (eastern North America and Eastern Hemisphere)
October 27/28	Total lunar eclipse (Americas, Europe)
November 4	Close conjunction between Venus and Jupiter

2005

April 8	Annular/total solar eclipse (Pacific, Central and South America)
October 3	Annular solar eclipse (Spain, Africa)

2006

March 29	Total solar eclipse (Africa, Turkey, Asia)
June 17	Close conjunction between Mars and Saturn
August 26	Very close conjunction between Venus and Saturn
September 22	Annular solar eclipse (eastern South America, Atlantic)
November 8	Transit of Mercury (North and South America)

2007

March 3	Total lunar eclipse (Europe, Africa)
August 28	Total lunar eclipse (western North America, Pacific)

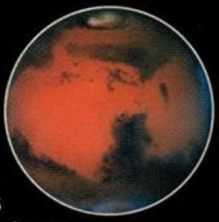
2008

February 1	Close conjunction between Venus and Jupiter
February 20/21	Total lunar eclipse (Americas, western Europe)
July 10	Close conjunction between Mars and Saturn
August 1	Total solar eclipse (northern Canada, Russia, China)

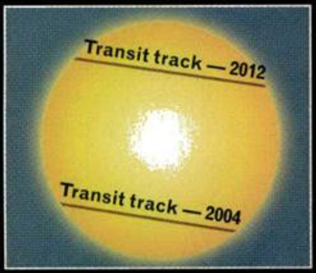
2009

January 26	Annular solar eclipse (Indonesia)
April 22	Lunar occultation of Venus at dawn (western North America)
July 22	Total solar eclipse (India, China, Pacific)
All year	Saturn's rings edge-on

August 27, 2003


NASA/STScI

Every 15 or 17 years, Mars approaches particularly close to Earth. The Red Planet then shines brighter and looms larger in a telescope than at any other time. Our last close-up view came in September 1988, but August 2003 promises to be even better. Mars will then be just 34.7 million miles from Earth — closer than it's been in more than 1,000 years.



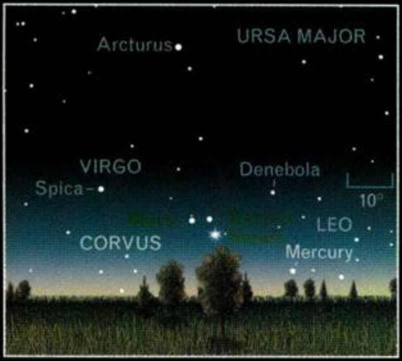
June 8, 2004 and June 5/6, 2012

Transits of Venus are the stuff of legends. No more than twice each century, Venus passes directly between the sun and Earth, appearing as a fuzzy black dot on the face of the sun. Such transits come in pairs eight years apart, with each pair separated by either 113 or 130 years. The last pair occurred in 1874 and 1882, and the next will be in 2004 and 2012.

2009

Approximately every 15 years, the rings of Saturn tilt edge-on to our line of sight. Because the rings are so thin, they seem to disappear from view when seen through most telescopes — even a large scope has a hard time showing the razor-thin rings. We have two opportunities in the next 25 years to witness a ring-plane crossing, in 2009 and 2025.

Charles F. Capen



August 5, 2010

With the planets in constant motion, it's not unusual to see two or more of them grouped in the sky at one time. One of the nicest such conjunctions featuring three planets appears in the evening sky of August 5, 2010. Venus, Mars, and Saturn then appear equally spaced in the twilight sky, lurking low in the west after sunset.

July 1, 2015

Planetary conjunctions may seem like a dime a dozen, but it's always special when the two brightest planets join up. Venus and Jupiter come within half a degree of one another in the evening sky on July 1, 2015. They will then be separated by the diameter of a full moon, close enough to view both in the same telescopic field of view.

John McNeal

2010

January 15	Annular solar eclipse (Africa, southern Asia)
July 11	Total solar eclipse (Pacific, southern South America)
August 5	Evening conjunction of Venus, Mars, and Saturn
December 21	Total lunar eclipse (North and Central America, Pacific)

2011

May 11	Close conjunction between Venus and Jupiter
June 15	Total lunar eclipse (Asia, Africa)
December 10	Total lunar eclipse (western North America, Pacific, Australia, Asia)

2012

May 20	Annular solar eclipse (China, Japan, Pacific, United States)
June 5/6	Transit of Venus (North America, Pacific, Asia, Australia)
November 13	Total solar eclipse (Australia, Pacific)

2013

May 10	Annular solar eclipse (Australia, Pacific)
November 3	Annular/total solar eclipse (Atlantic, Africa)

2014

April 15	Total lunar eclipse (North and South America)
August 18	Close conjunction between Venus and Jupiter
October 8	Total lunar eclipse (western North America, Pacific)

2015

February 21	Close conjunction between Venus and Mars
March 20	Total solar eclipse (Atlantic, North Sea, North Pole)
April 4	Total lunar eclipse (western North America, Pacific, Australia)
July 1	Close conjunction between Venus and Jupiter
September 27/28	Total lunar eclipse (Americas, western Europe, Africa)
October 22	Morning conjunction of Venus, Mars, and Jupiter

2016

January 9	Very close conjunction between Venus and Saturn
March 9	Total solar eclipse (Indonesia, Pacific)
May 9	Transit of Mercury (Americas, Europe, Africa)
August 27	Very close conjunction between Venus and Jupiter
September 1	Annular solar eclipse (central Africa)

2017

February 26	Annular solar eclipse (South America, Atlantic, Africa)
August 21	Total solar eclipse (United States)

2018

January 31	Total lunar eclipse (western North America, Pacific, Australia, Asia)
July 27	Total lunar eclipse (Europe, Africa, Asia)
July 27	Very close approach of Mars

2019

January 20/21	Total lunar eclipse (Americas, western Europe, Africa)
July 2	Total solar eclipse (Pacific, South America)
November 11	Transit of Mercury (Americas, Europe, Africa)
December 26	Annular solar eclipse (southern Asia)

2020

June 21	Annular solar eclipse (Africa, Asia, Pacific)
December 14	Total solar eclipse (Pacific, South America, Atlantic)
December 21	Close conjunction between Jupiter and Saturn

2021

May 26	Total lunar eclipse (western North America, Pacific, Australia)
June 10	Annular solar eclipse (central Canada, North Pole, Russia)

2022

May 15/16	Total lunar eclipse (Americas)
May 29	Close conjunction between Mars and Jupiter
November 8	Total lunar eclipse (North America, Pacific)

2023

April 20	Annular/total solar eclipse (Australia, Indonesia, Pacific)
October 14	Annular solar eclipse (United States, Mexico, Central and South America)

2024

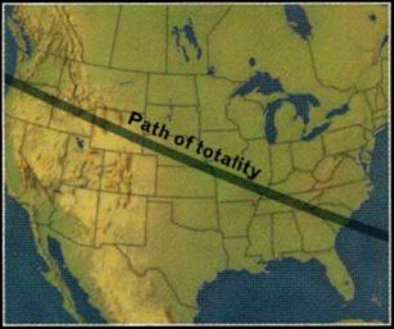
April 8	Total solar eclipse (Pacific, Mexico, United States, eastern Canada, Atlantic)
August 14	Close conjunction between Mars and Jupiter
October 2	Annular solar eclipse (Pacific, southern South America)

2025

All year	Saturn's rings edge-on
March 13/14	Total lunar eclipse (Americas)
September 7	Total lunar eclipse (Asia, Australia)

2026

March 3	Total lunar eclipse (western North America, Pacific, Australia, Asia)
August 12	Total solar eclipse (Greenland, Iceland, Spain)



August 21, 2017

The long wait will officially end on August 21, 2017, when the moon's dark umbral shadow hits the United States for the first time since July 1991. The total solar eclipse will last up to 2 minutes and 40 seconds along a path that runs across the central part of the country, starting on the Oregon coast and ending in coastal South Carolina.

May 15/16 and November 8, 2022

Although lunar eclipses occur fairly frequently, 2022 offers something that no other year in the next 25 can. A pair of long total eclipses — where the moon lies completely immersed in Earth's dark umbral shadow — will then grace the sky above North America, bringing a combined sum of nearly three hours of totality.

Dan Schecter

August 8, 2024

While most people are pointing toward August 2017, when the long drought without a total solar eclipse ends for those in the United States, a better eclipse awaits just seven years later. On August 8, 2024, the sun will disappear for up to 4½ minutes along a path that stretches from Mexico northeastward through Texas and on up to New England.

Brian Tkachyk

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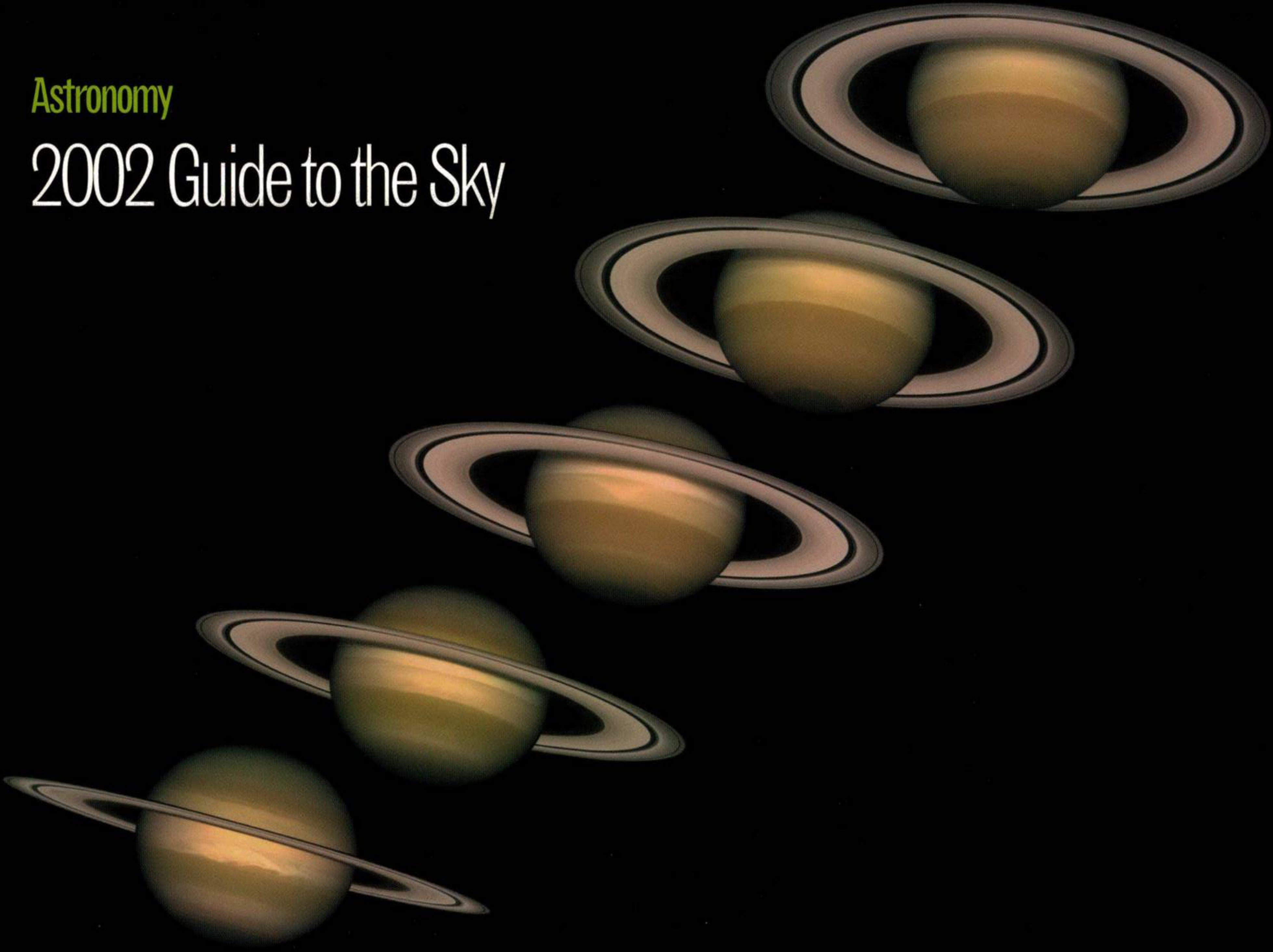
Astronomy

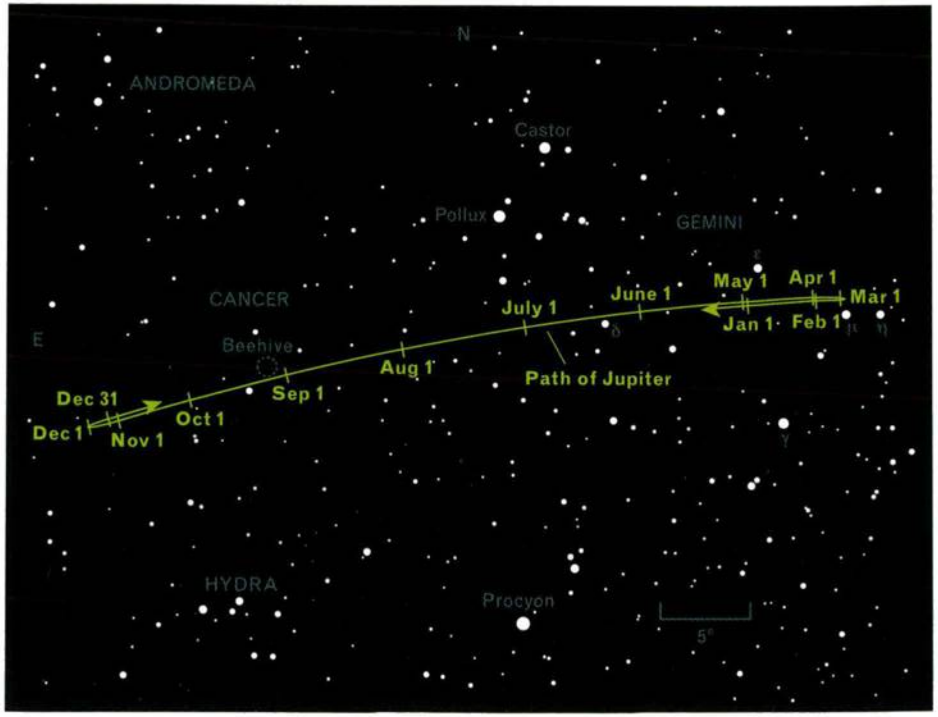
2002 Guide to the Sky

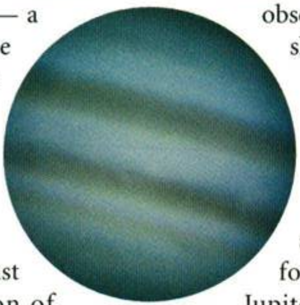


JAN

Jupiter at Its Best

Jupiter remains bright all winter. You'll find it on a New Year's night as it passes almost overhead at midnight, dominating the constellation of Gemini the Twins. Jupiter brings in the New Year standing directly opposite the sun in our sky, a moment called opposition.




Mark Coco

At opposition, Jupiter rises at sunset and sets at sunrise, staying visible all night long. It also appears largest at opposition, making it an awesome sight in a telescope. Jupiter's the biggest planet in the solar system — a staggering 12 times the diameter of our home planet — and rotates the fastest, making one complete revolution in 9 hours and 55 minutes at the equator.

Because winter nights last so long, an entire rotation of Jupiter can be observed in a single night. Jupiter's atmosphere is chock full of details, many of which are visible in small telescopes. (Though remember that seeing fine details on any planet often involves a test of patience, waiting for those few precious seconds of steady seeing.) With winds in excess of 1,000 miles per hour, daily changes in Jupiter's clouds become evident to the careful observer who records what he or she sees.

Jupiter's path among the stars this month carries it westward toward Mu (μ) Geminorum. By February 22, Jupiter stands north of that star with the moon just above for North American viewers. Jupiter resumes its easterly path against the background stars in early March.

The moon occults Jupiter three times this year as seen from various parts of the world. These events prove spectacular in a small telescope as first some of the moons, then the disk of Jupiter, and finally the remaining moons disappear behind our moon's limb. Some of these occultations take place in daylight for some locations. The January 26 event can be viewed from the northern regions of Europe, Asia, and North America. During the early morning hours of February 23, Jupiter's disk disappears for European observers. (This event can be seen from

Alaska and northern Canada on the previous night.) Arctic regions can view the March 22 occultation during daylight.

Jupiter ranks among the most rewarding planets to observe because small telescopes show many features. You can get even more out of observing if you time the moment obvious features cross the central meridian of the planet — that is the imaginary line that bisects the planet's visible disk through each pole. By combining these accurate timings with detailed tables of the longitude of the central meridian for each day, the actual longitude of features can be measured using no more equipment than a small telescope, accurate watch, and a good eyeball. Measurements of the same feature over a few nights may reveal that the feature is drifting noticeably in longitude. Other turbulent features come and go over periods of a few days.

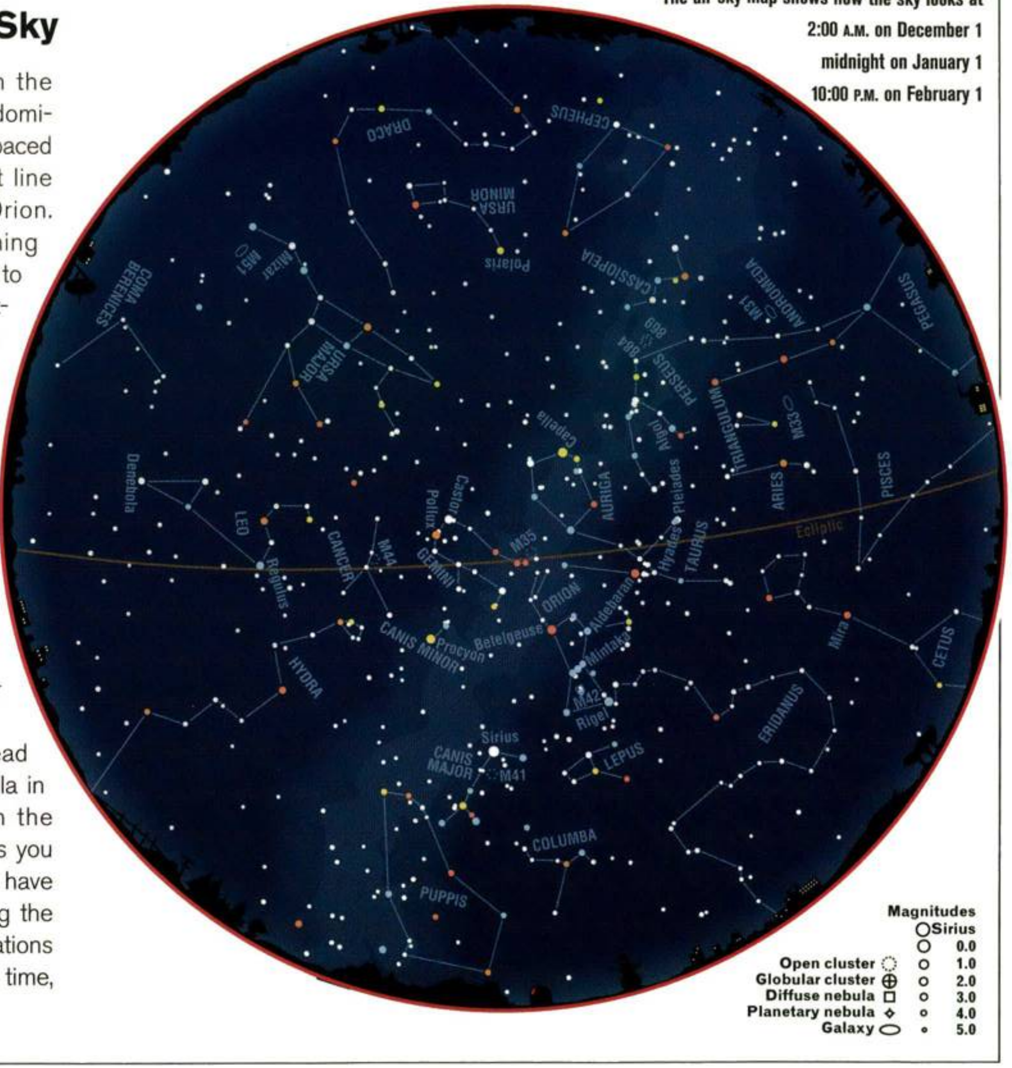
Another worthwhile project involves observing the relative positions of the jovian moons from night to night. You'll quickly become familiar with the four bright moons: Io, Europa, Ganymede, and Callisto. Furthermore, you'll notice each of the satellites frequently passes behind or in front of Jupiter. Such occultations and transits can also be timed. Indeed, it was such simple observations that led to one of the first accurate determinations of the speed of light.

Exploring the Winter Sky

One of the major signposts in the entire sky, Orion the Hunter, dominates the winter sky. Three closely spaced 2nd-magnitude stars in a straight line form the unmistakable belt of Orion. Extending the imaginary line joining these stars to the upper right leads to Taurus the Bull and its orangish 1st-magnitude star, Aldebaran. Reverse the direction of your gaze to the belt's lower left and you cannot miss Sirius the Dog Star – brightest in all the heavens at magnitude −1.5.

Now move perpendicular to the belt from its westernmost star and find at the upper left of Orion the red supergiant star, Betelgeuse. Continuing this line brings you to a pair of bright stars, Castor and Pollux in Gemini the Twins.

Above Orion and nearly overhead on winter evenings is brilliant Capella in Auriga. Extending a line through the shoulders of Orion to the east leads you to Procyon in Canis Minor. Once you have these principal stars mastered, using the chart to discover the fainter constellations will be a whole lot easier. Take your time, and enjoy the journey.


The all-sky map shows how the sky looks at
2:00 A.M. on December 1
midnight on January 1
10:00 P.M. on February 1

DRACO
CEPHEUS
URSA MINOR
Polaris
CASSIOPEIA
ANDROMEDA
M31
PEGASUS
COMA BERENICES
M51
Mizar
URSA MAJOR
869
884
PERSEUS
Algol
TRIANGULUM
M33
Capella
AURIGA
Pleiades
ARIES
PISCES
Ecliptic
Denebola
LEO
Regulus
CANCER
M44
Castor
Pollux
GEMINI
M35
Hyades
TAURUS
ORION
Aldebaran
Mintaka
Betelgeuse
CANIS MINOR
Procyon
HYDRA
M42
Rigel
Mira
CETUS
ERIDANUS
Sirius
CANIS MAJOR
M41
LEPUS
COLUMBA
PUPPIS
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

S	M	T	W	T	F	S
		1	2	3	4	◐
6	7	8	9	10	11	12
○	14	15	16	17	18	19
20	◑	22	23	24	25	26
27	●	29	30	31		

EST

1 **1 A.M.**
Jupiter is at opposition

11 **6 P.M.**
Mercury is at greatest eastern elongation (19°, evening)

14 **7 A.M.**
Venus is in superior conjunction

18 **5 P.M.**
The moon passes 5° south of Mars

24 **11 A.M.**
The moon passes 0.08° north of Saturn

26 **2 A.M.**
The moon passes 0.9° north of Jupiter

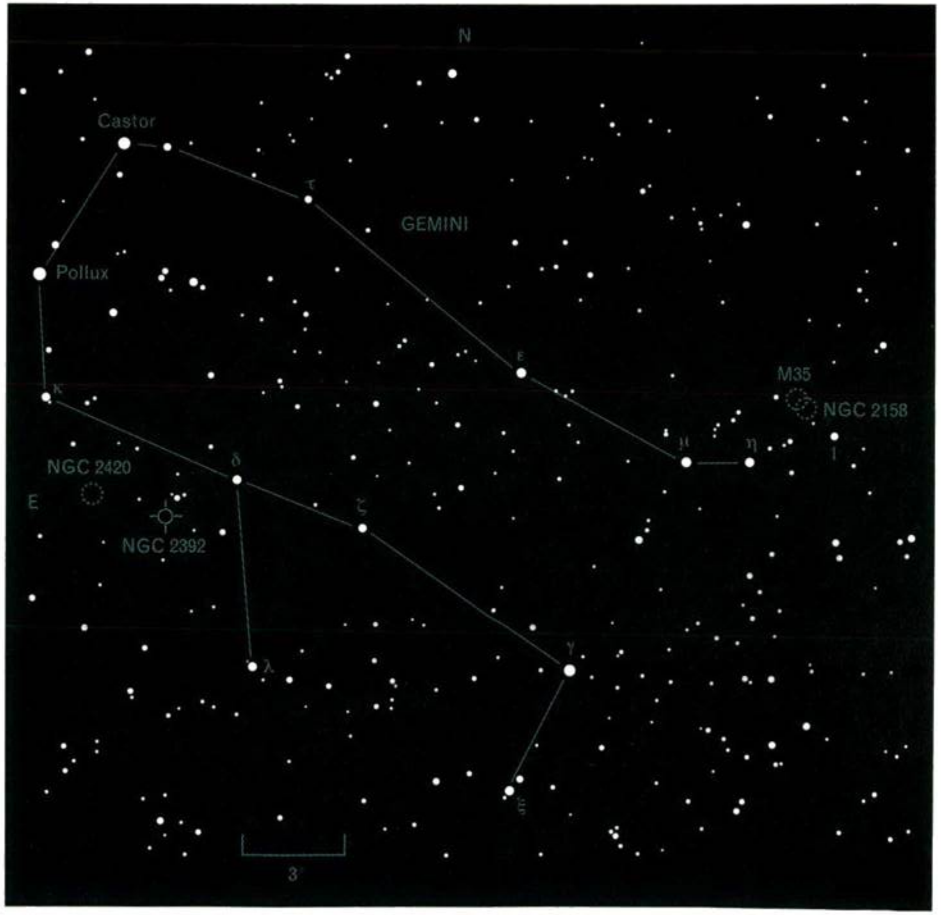
27 **2 P.M.**
Mercury is in inferior conjunction

28 **9 A.M.**
Neptune is in conjunction with the sun

Events in **red** are ones you won't want to miss. All times in the calendar are eastern time. "Morning" or "evening" at the end of a listing denotes that the event appears before sunrise or after sunset, respectively.

FEB

Seeing Double in Gemini



Only two constellations share the distinction of lying both on the ecliptic and in the plane of the Milky Way. The former marks the apparent track of the sun across our sky – a path followed closely by the moon and planets – while the latter boasts the highest density of star clusters and nebulae in our galaxy. These two facets place Gemini, in the winter sky, and summer's Sagittarius among the top destinations for planetary and deep-sky observers alike.

Luke Dodd

Throughout the winter and spring of 2002, Gemini the Twins plays host to the brilliant planet Jupiter. Simply find the brightest point of light in the sky during January or February and you'll be looking at Jupiter; then use it to trace the outline of Gemini. (From March onward Venus outshines Jupiter in the evening sky.) Gemini will also be the stellar backdrop in early June when Venus first catches up with and then passes mighty Jupiter.

But don't view Gemini as simply a nice canvas on which the planets play. This ancient constellation forms a conspicuous pattern that resembles an oblong box. At one end of the box stand the twin stars Castor and Pollux, the brightest in the constellation. From there two nearly parallel lines of fainter stars run to the west-southwest.

Although Castor, which lies about 5° north of Pollux, glows slightly fainter, it's a far more intriguing star. If you view

Castor with a modest telescope on a night of steady seeing, you'll resolve it into a pair of suns. It ranks among the finest double stars in the northern sky, a fact known since the 17th century. But it was not until 1803 that Sir William Herschel announced that the two are gravitationally bound and revolve around each other. It was the first object outside our solar system shown to be acting under the influence of gravity.

These two stars orbit with a period of more than 500 years. A third star, located well away from the other two and glowing at 9th magnitude, also belongs to the system. But most interesting, each of these three stars is itself a binary (though none can be resolved in backyard instruments), making Castor a bona fide six-star system.

The two most conspicuous star clusters in Gemini lie next to each other at the feet of the twins. The spectacular M35 holds dozens of stars brighter than 10th magnitude and some 200 stars in total. Combined, they equal the light of a 5.1-magnitude star, making the cluster visible to the naked eye from a dark site. A fainter open cluster, NGC 2158, lies in the same low-power field of view.

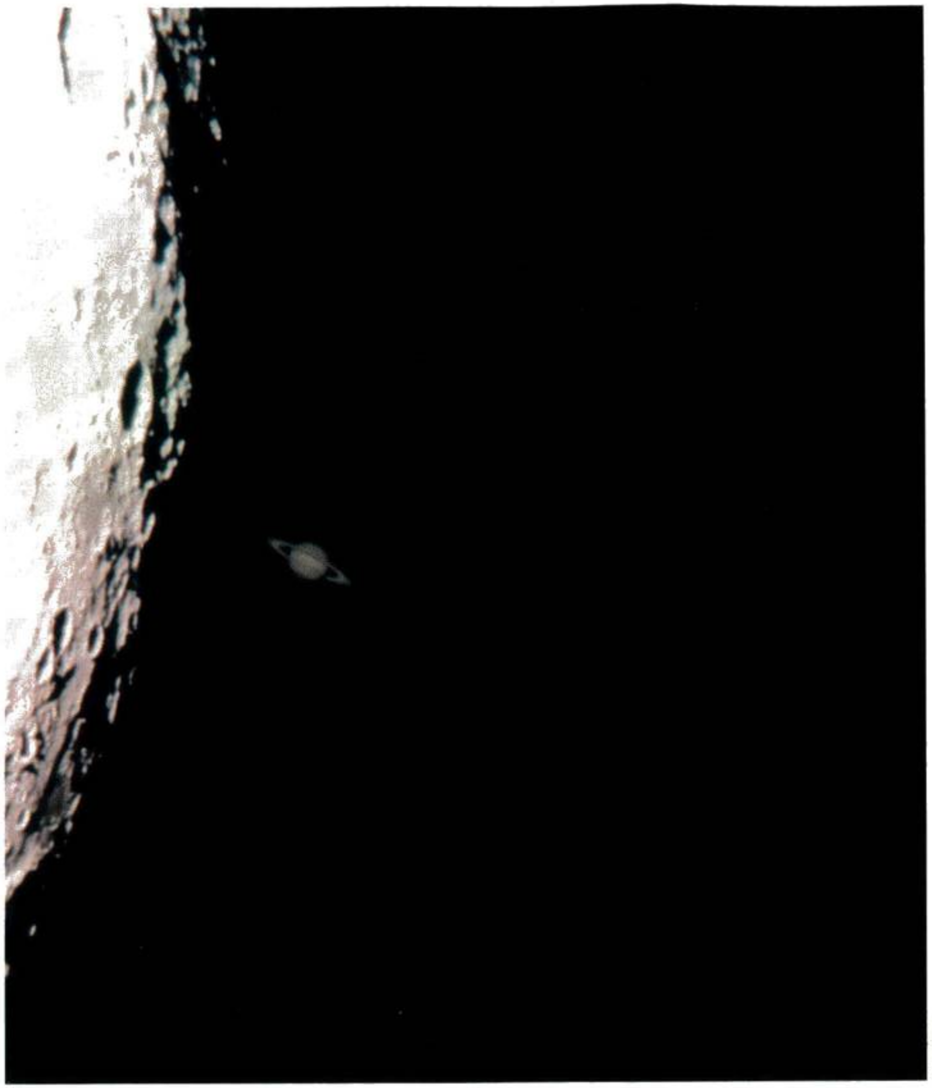
An appropriate target for these chilly winter nights is the planetary nebula known as the Eskimo (NGC 2392). Photographs of this object reveal a reasonable facsimile of a human face surrounded by a fur collar. The view through a telescope isn't quite so graphic, though you should be able to see a bluish disk divided into two concentric shells.

The Moon Hides Saturn

As the moon traverses the sky each month, it regularly passes between distant objects and observers on Earth. If you include faint stars, such occultations happen all the time. But bright stars and planets are occulted far less frequently, making those events worth watching. Although no 1st-magnitude stars get occulted in 2002, several planets do. For those in the United States, the finest involves everyone's favorite planet, Saturn.

In the early evening hours of February 20, the first quarter moon passes in front of the Ringed Planet. The time depends on your exact location, but roughly it occurs around 7 P.M. EST (6 P.M. CST, 5 P.M. MST, and 4 P.M. PST).

Such occultations are easy to watch. Simply point your telescope at the moon and watch as it approaches the planet. Saturn's ring system is so big that it takes the moon nearly a full minute to hide it completely from view. Because the moon is waxing, Saturn disappears behind the dark limb and reappears from behind the bright limb. Both should be a snap to see, however, because Saturn is so bright.



Chris Cook

S	M	T	W	T	F	S
					1	2
3	◐	5	6	7	8	9
10	11	○	13	14	15	16
17	18	19	◑	21	22	23
24	25	26	●	28		

EST

9 midnight
The moon passes 5° south of Mercury

10 8 P.M.
Asteroid Juno is at opposition

13 noon
Uranus is in conjunction with the sun

16 7 P.M.
The moon passes 5° south of Mars

20 7 P.M.
The moon passes 0.2° north of Saturn

21 11 A.M.
Mercury is at greatest western elongation (27°, morning)

22 9 P.M.
The moon passes 0.9° north of Jupiter

24 8 A.M.
Mercury passes 0.5° south of Neptune (morning)

MAR

Spying the False Dusk

One of the special sights seen in the night sky – but by only a few people – is the zodiacal light. Often mistaken for twilight, the zodiacal light has been recognized since the 17th century, although it was undoubtedly seen by ancient observers. The best times of the year for Northern Hemisphere observers to see this elusive glow come on springtime evenings and autumn mornings. In both these seasons, the ecliptic makes its steepest angle to the horizon, which improves the light's visibility.

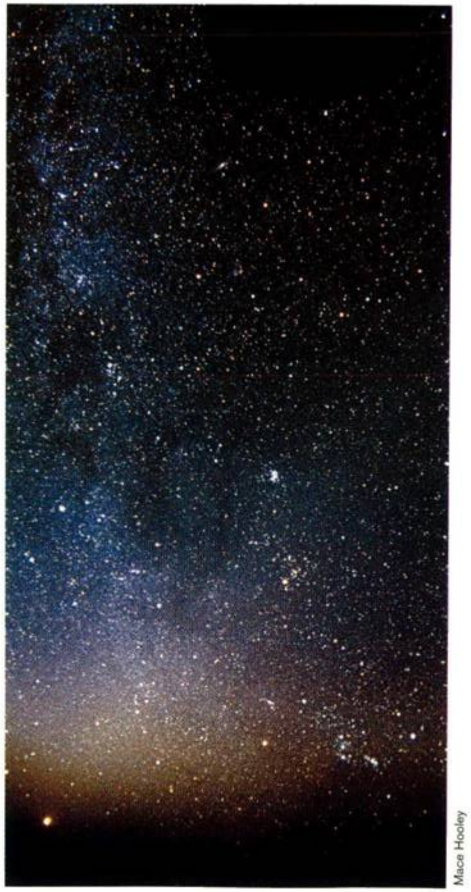
The zodiacal light appears as a cone-shaped, whitish glow that aligns along the ecliptic. After sunset, twilight may appear to linger somewhat longer than usual. The cone rises up from a broad base and persists long after sunset. It is generally dimmer than the Milky Way, though its central regions can appear brighter. It gets fainter and narrower as it climbs upward and blends into the sky background. Consequently, you need a very dark sky and no interfering streetlights or moonlight.

Experience shows that the evening zodiacal light is often best seen by averting your vision from the ecliptic and rapidly scanning your eyes along the horizon on either side of due west. In doing so, concentrate your awareness to the ecliptic, and note any extended cone of light. Using this technique, the faint glow often jumps out at you.

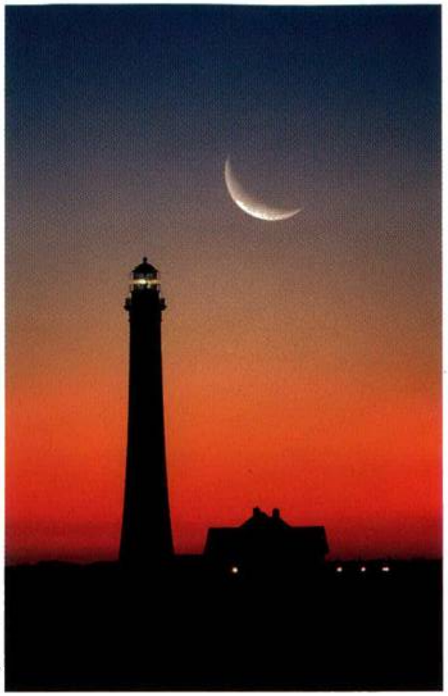
In March and April, see how far the glow extends. Does it reach past the Pleiades and into Gemini? On autumn mornings, the cone becomes evident well before twilight begins, at least two hours before sunrise. It then stretches past Leo and into Cancer, and sometimes beyond.

The zodiacal light results from sunlight scattering off fine dust particles that pervade the solar system. Most of these particles are confined to the ecliptic, an observation confirmed by the Infrared Astronomical Satellite when it captured these dust bands. Photographing the zodiacal light is difficult because of its low intensity. The best regions of the United States to see it are high desert regions such as southern Utah and northern Arizona, where the zodiacal light can be seen on almost any clear, moonless evening.

The zodiacal light is a remarkable sight to see, once you realize that it represents the debris from millions of comets that have passed through the inner solar system and deposited their dust along the way. The fine debris, essentially trillions of meteoroids, was not well understood a hundred years ago. Now the elusive glow has been identified, and this merely adds to the wonder felt when seeing the zodiacal light for the first time.



Mace Hooley



Larry Landolfi

Search for the Young Moon

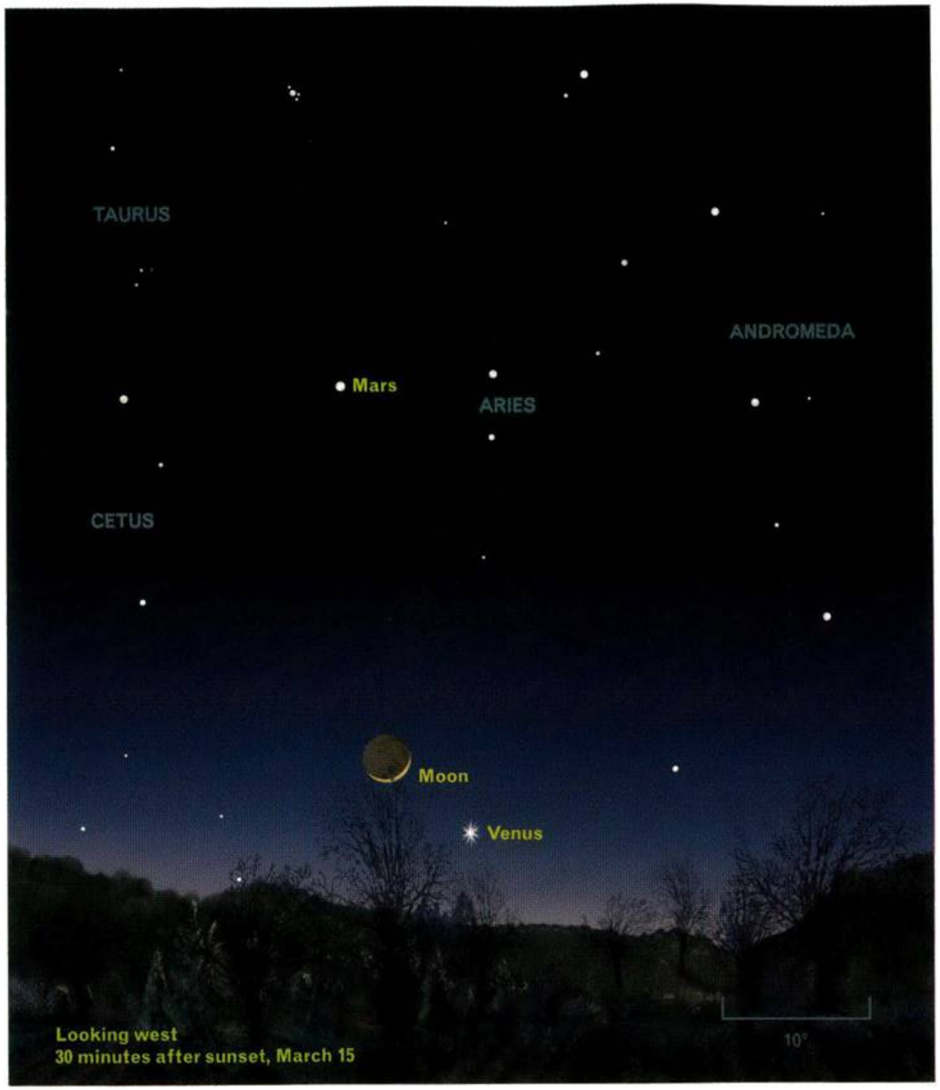
Few things look as precious as a slender crescent moon hanging low in the twilight sky. The ghostly crescent seems nearly lost in the pinks, oranges, and reds of the twilight. This month offers the best time of 2002 to spot a very young moon, and its equally impressive cousin that shows up on succeeding nights.

Spotting the thin crescent depends on the time of year, the age of the moon, and observing conditions. Early spring is best because the ecliptic makes a steep angle to the western horizon after sunset — the same reason the zodiacal light is easier to see. Thus the angular separation of the moon from the sun translates into altitude above the horizon.

The moon's age measures the time since new moon, the instant when our satellite passes between Earth and the sun. Seeing a one-day old or younger moon requires a concerted effort. The record for the youngest moon ever spotted stands at around 12 hours.

Conditions also must be just right for spotting a very young moon. First, the moon lies only a few degrees high, so choose an observing site that provides a clear view down to the horizon. Any haze or clouds will have you pondering what might have been.

Your best opportunity to spot a young moon this year comes on March 14. New moon arrives at 9:02 P.M. EST on the 13th, so on the 14th the moon will be about 21 hours old on the East Coast and 24 hours old on the West Coast. It will be just 1 percent lit and lie about 3° above the horizon 20 minutes after sunset. Use Venus, which lies 7° above and a little to the right, as a guide. Binoculars will help you spot the moon, but then set them aside and see whether you can glimpse it with your naked eye.



Looking west
30 minutes after sunset, March 15

S	M	T	W	T	F	S
					1	2
3	4	◐	6	7	8	9
10	11	12	○	14	15	16
17	18	19	20	◑	22	23
24/31	25	26	27	●	29	30

EST

8 **10 P.M.**
Mercury passes 1.2° south of Uranus (morning)

10 **4 A.M.**
The moon passes 4° south of Neptune

11 **noon**
The moon passes 4° south of Uranus
8 P.M.
The moon passes 3° south of Mercury

17 **8 P.M.**
The moon passes 4° south of Mars

20 **5 A.M.**
The moon passes 0.5° north of Saturn
2 P.M.
Equinox (northern spring/southern autumn begins)

22 **7 A.M.**
The moon passes 1.1° north of Jupiter

31 **11 A.M.**
Saturn passes 4° north of Aldebaran (evening)

APR

A Beautiful Planetary Grouping

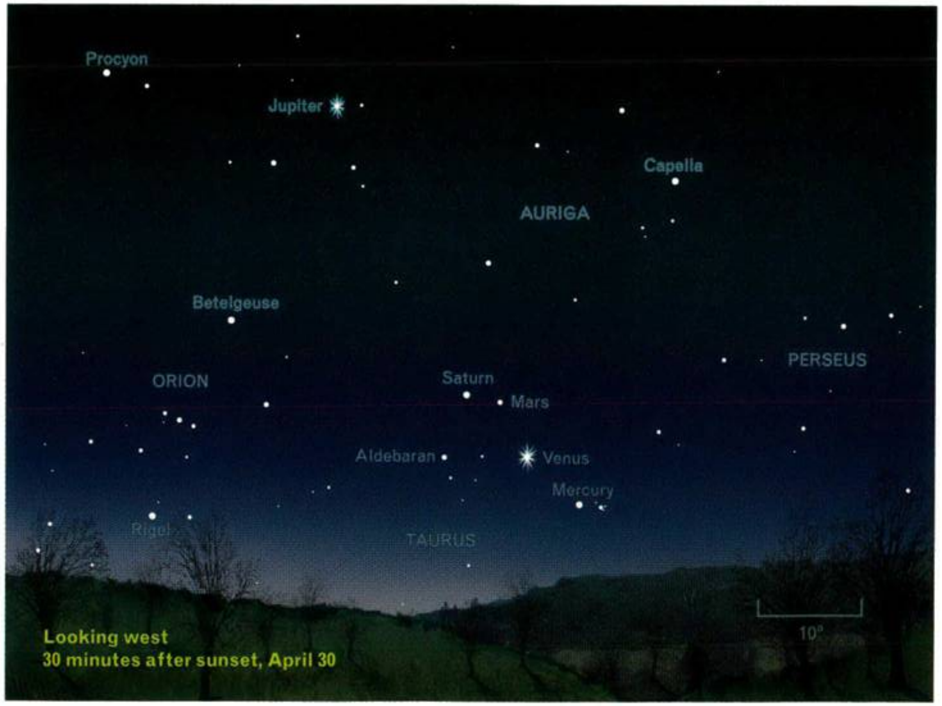
Drama in the western sunset occurs this month and next. Five planets line up in a beautiful procession across the evening twilight sky. Mars, Jupiter, and Saturn lie on the far side of the solar system and will slide deeper into the twilight. As they do, both inner planets, Mercury and Venus, rise out of the sun's glow to meet each one in turn, providing a series of dramatic planetary conjunctions that will attract attention as each world passes by another — a real world series.

First pitch on April 1 occurs shortly after sunset. Venus, the brightest planet, pops out of the twilight first, lying low in the west. It also sets first, only 90 minutes after the sun. Strung along a 66°-long arc through three zodiacal constellations lie three more planets. Venus lies in Aries the Ram. Mars begins in Aries and quickly moves into Taurus the Bull during the first week of April. Higher still is Saturn, also in Taurus, followed by Jupiter way up in Gemini the Twins. By the end of the month, Venus, Mars, and Saturn will all lie within a 3°-wide circle. Mercury joins the game at midmonth.

The next 40 days provide a changing nightly spectacle as each planet continually changes position, caused by a combination of their motion around the sun and ours.

A crescent moon catches up with Venus on April 14, lying 3° to its left. The moon then passes the next three planetary bases in this celestial ball game. On April 15 the moon passes 2° to the left of Mars; on April 16 it's 2° above Saturn; and two days later the growing crescent lies just 1° to the upper right of Jupiter.

While this is happening, Mercury wings its way into the evening twilight and becomes easier to see. As it climbs it dims, but appears in a darker sky. On April 20 it shines at magnitude –1.1 and lies 15° from the sun. Mercury tries to catch up with Venus but fails. The closest it gets is on April 30, when the pair is separated by 6°. Mercury lies next to the Pleiades star cluster (M45) on the same night and shines at magnitude 0.0. It reaches its greatest elongation east of the sun (21°) on May 3/4.



Looking west
30 minutes after sunset, April 30

Venus continues to climb toward Mars and Saturn and on May 5 the spectacular triple planet conjunction begins with the three planets within a 3°-wide circle. Mercury lies 6.5° to the lower right of Venus.

Five days later Venus brushes Mars, with only 0.3° separating them. While Mars is relatively faint at magnitude 1.7,

Gianni Tumino

Venus is dazzling at magnitude –3.9. Both appear in a low-power telescopic field. Watch when the crescent moon joins the group on May 13 and 14. Venus continues on its path for more conjunctions. It passes 2° north of Saturn on May 7 and 1.6° north of Jupiter on June 3.

In the game of celestial mechanics, planetary alignments are not rare. A similar grouping occurred on May 5, 2000, although it appeared only in daylight.

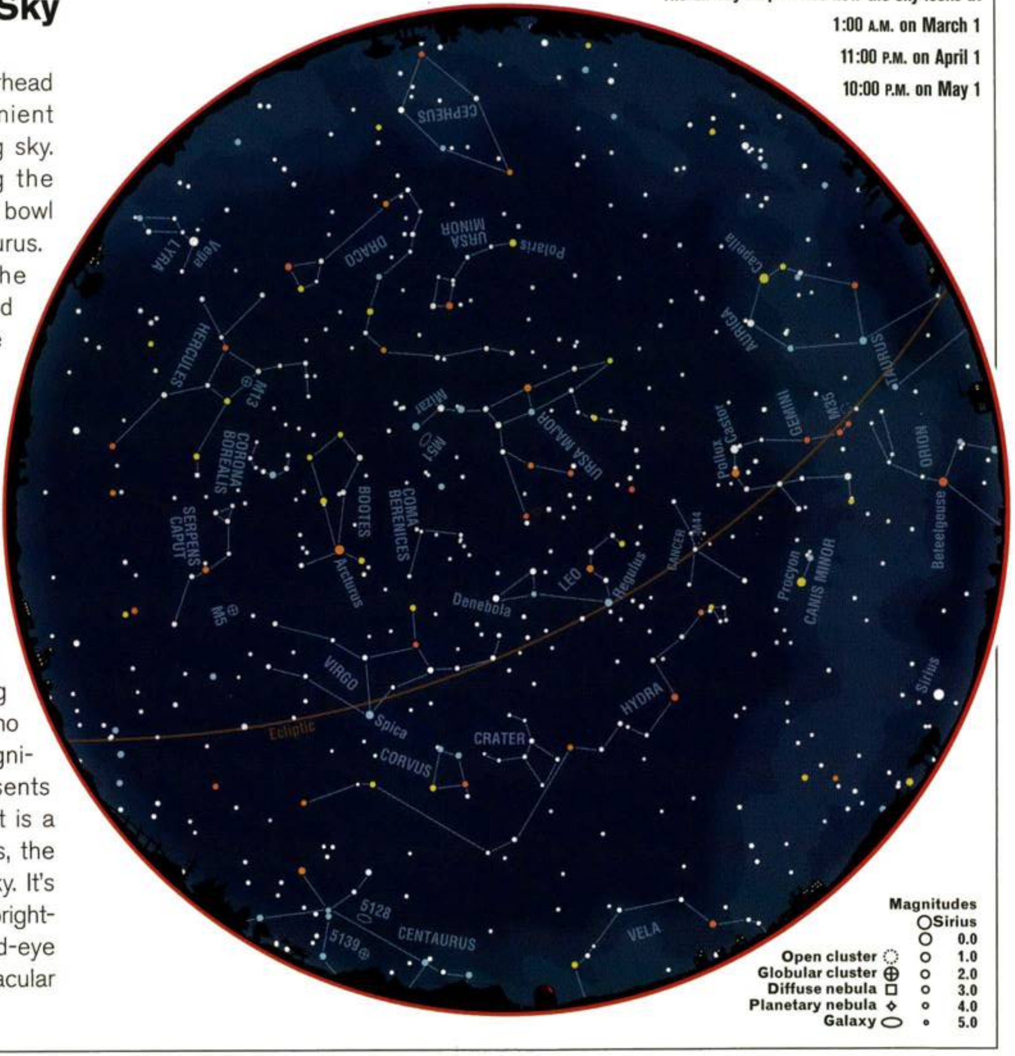
Exploring the Spring Sky

The Big Dipper swings high overhead on spring evenings, a convenient signpost for the rest of the spring sky. Follow the arc of stars forming the handle of the Dipper away from the bowl and you will land on brilliant Arcturus. This orangish star dominates the spring sky in the kite-shaped constellation Boötes. Well to the west of Boötes lies Leo the Lion. You can find its brightest star, Regulus, by using the pointers in the Dipper in reverse.

To the southeast of Leo is the realm of the galaxies and the constellation Virgo the Maiden. Virgo's brightest star, Spica, shines at magnitude 1.0.

Midway between Arcturus and Vega, the bright "summer" star rising in the northeast, is a region where no star shines brighter than 2nd magnitude. A semicircle of stars represents Corona Borealis, and adjacent to it is a large region that houses Hercules, the fifth-biggest constellation in the sky. It's here we can find the northern sky's brightest globular cluster, M13. A naked-eye object from a dark site, it is spectacular when viewed through a telescope.

The all-sky map shows how the sky looks at
1:00 A.M. on March 1
11:00 P.M. on April 1
10:00 P.M. on May 1


CEPHEUS
URSA MINOR
Polaris
DRACO
LYRA
Vega
HERCULES
M13
CORONA BOREALIS
SERPENS CAPUT
M5
BOOTES
Arcturus
COMA BERENICES
M51
Mizar
URSA MAJOR
LEO
Regulus
Denebola
CANCER
M44
Pollux
Castor
GEMINI
M35
AURIGA
Capella
TAURUS
ORION
Betelgeuse
CANIS MINOR
Procyon
Sirius
HYDRA
CRATER
CORVUS
Spica
VIRGO
Ecliptic
CENTAURUS
5128
5139
VELA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

S	M	T	W	T	F	S
	1	2	3	◐	5	6
7	8	9	10	11	○	13
14	15	16	17	18	19	◑
21	22	23	24	25	●	27
28	29	30				

EDT

6 **11 A.M.** EST
The moon passes 4° south of Neptune

7 **5 A.M.**
Mercury is in superior conjunction
9 P.M.
The moon passes 4° south of Uranus

14 **1 P.M.**
The moon passes 3° south of Venus

15 **7 P.M.**
The moon passes 2° south of Mars

16 **4 P.M.**
The moon passes 0.8° north of Saturn

18 **7 P.M.**
The moon passes 1.6° north of Jupiter

22 Lyrid meteor shower peaks

29 **9 A.M.**
Mars passes 6° north of Aldebaran (evening)

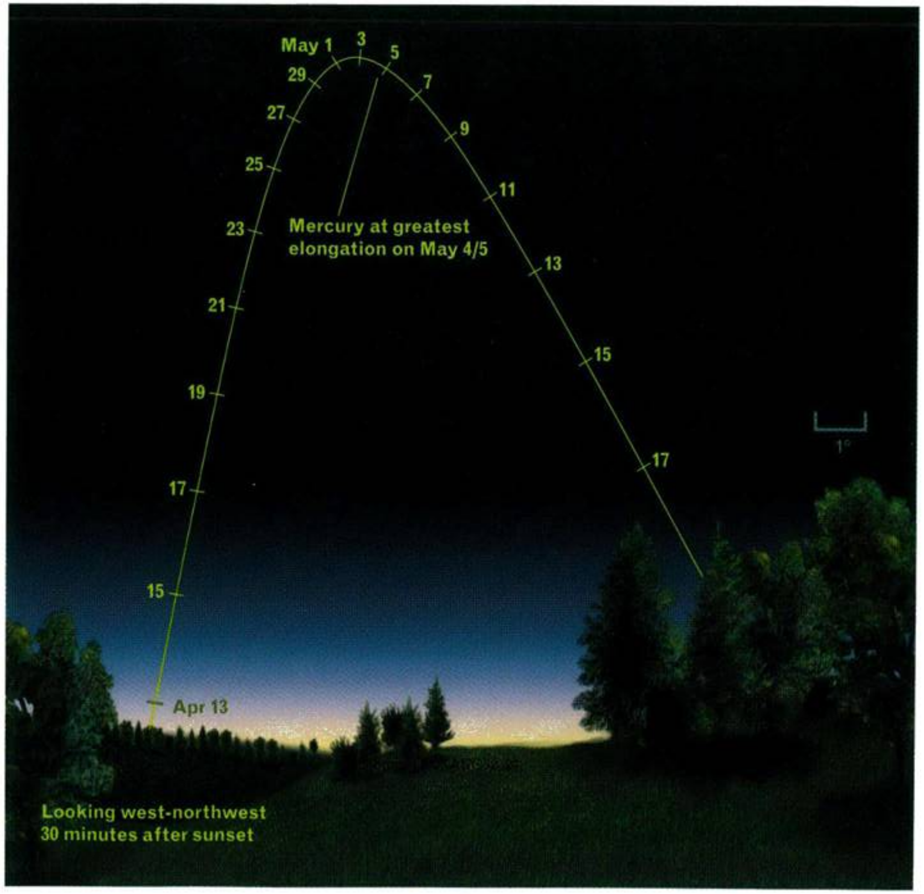
MAY

Catch a Glimpse of Mercury

Even at the best of times, Mercury makes only brief visits to the twilight sky. Fortunately, the balmy evenings of May host the best opportunity of the year to view this normally elusive inner planet. The problem with observing Mercury stems from the planet's proximity to the sun. It never lies more than 43 million miles from our star, while Earth orbits at a distance of some 93 million miles. So from our vantage point, Mercury never strays far from the blinding glare of the sun. This means the planet can only appear in a twilight sky, either in the west shortly after sunset or in the east just before sunrise.

Mercury passed on the far side of the sun as seen from Earth on April 7 and has since been zipping around its orbit, climbing quickly away from the sun and into the evening sky. The peak of this apparition comes on May 3/4, when the planet reaches greatest elongation and lies 21° east of the sun. On that night it appears 14° high in the west-northwest 30 minutes after the sun goes down.

May's apparition is helped immensely by the steep angle of the ecliptic — the apparent path of the sun across the sky that the moon and planets also closely follow — to the western horizon at dusk during springtime. Mercury's angular distance from the sun thus translates into altitude above the horizon, making the planet easier to see and extending its visibility after sunset.


May 1
3
5
29
7
27
9
25
11
23
Mercury at greatest elongation on May 4/5
13
21
15
19
1°
17
17
15
Apr 13
Looking west-northwest 30 minutes after sunset

WHEN TO SEE MERCURY IN 2002

Evening Greatest elongation	Visible from	Peak altitude	Morning Greatest elongation	Visible from	Peak altitude
January 11	Jan. 1 to Jan. 22	10°	February 21	Feb. 3 to Mar. 29	7°
May 3	Apr. 16 to May 17	14°	June 21	June 6 to July 13	8°
September 1	July 29 to Sep. 21	5°	October 13	Oct. 5 to Oct. 31	11°
December 25	Dec. 1 to Dec. 31	9°			

Surprisingly, Mercury often lies farther from the sun than it does in May. On both February 21 and September 1, it reaches a greatest elongation of 27°. Yet, as the table shows, those are poor apparitions. That's because the table gives the peak altitude as seen at 40° north latitude either 30 minutes after sunset or 30 minutes before sunrise. In the Northern Hemisphere, the ecliptic makes its steepest angle on spring evenings and autumn mornings. The opposite occurs in the south, where observers see Mercury much higher. From Australia, it lies 20° high in both February and September.

This current appearance offers a great chance to view Mercury's changing size and phase with a telescope. On April 25, the planet appears 6.5" across and 63 percent lit; by May 3 it's 7.9" across and 38 percent lit, while on May 15 it appears 10.7" across with a phase of 10 percent.

The Moon Dims Slightly

On the morning of May 26, sharp-eyed observers may notice something different about the full moon. Look carefully and you might see that the southern half looks a little darker than the rest of the brilliant disk.

No, you aren't imagining anything. This is a lunar eclipse — although not the type you may be familiar with. Rather than a partial or total eclipse, the 26th brings a penumbral eclipse. If you were observing from the moon, Earth would be partially eclipsing the sun. Because the sun is so bright, there's still a lot of light reaching the moon, which is why it only appears slightly dimmed. The southern limb of the moon's disk is farther into Earth's shadow, so you'll notice the dimming more there.

The eclipse can be seen from anywhere the full moon is visible. That includes all areas in the Pacific Ocean as well as the western three-quarters of North America and the western half of South America. Our friends in eastern Asia, Australia, and New Zealand will also get a view, although for them the eclipse occurs on the evening of May 26. The penumbral eclipse begins at 6:13 A.M. EST (3:13 A.M. PST) and peaks at 8:03 A.M. EST (5:03 A.M. PST).

Robert Slobins

S	M	T	W	T	F	S
			1	2	3	◐
5	6	7	8	9	10	11
○	13	14	15	16	17	18
◐	20	21	22	23	24	25
●	27	28	29	30	31	

EDT

3 **midnight**
Mercury is at greatest eastern elongation (21°, evening)

4 **1 P.M.**
Mars passes 2° north of Saturn (evening)

5 Eta Aquarid meteor shower peaks

7 **2 P.M.**
Venus passes 2° north of Saturn (evening)

10 **5 P.M.**
Venus passes 0.3° north of Mars (evening)

13 **5 P.M.**
The moon passes 3° south of Mercury

14 **4 A.M.**
The moon passes 1.1° north of Saturn
3 P.M.
The moon passes 0.6° south of Mars
7 P.M.
The moon passes 0.8° south of Venus

16 **8 A.M.**
The moon passes 2° north of Jupiter

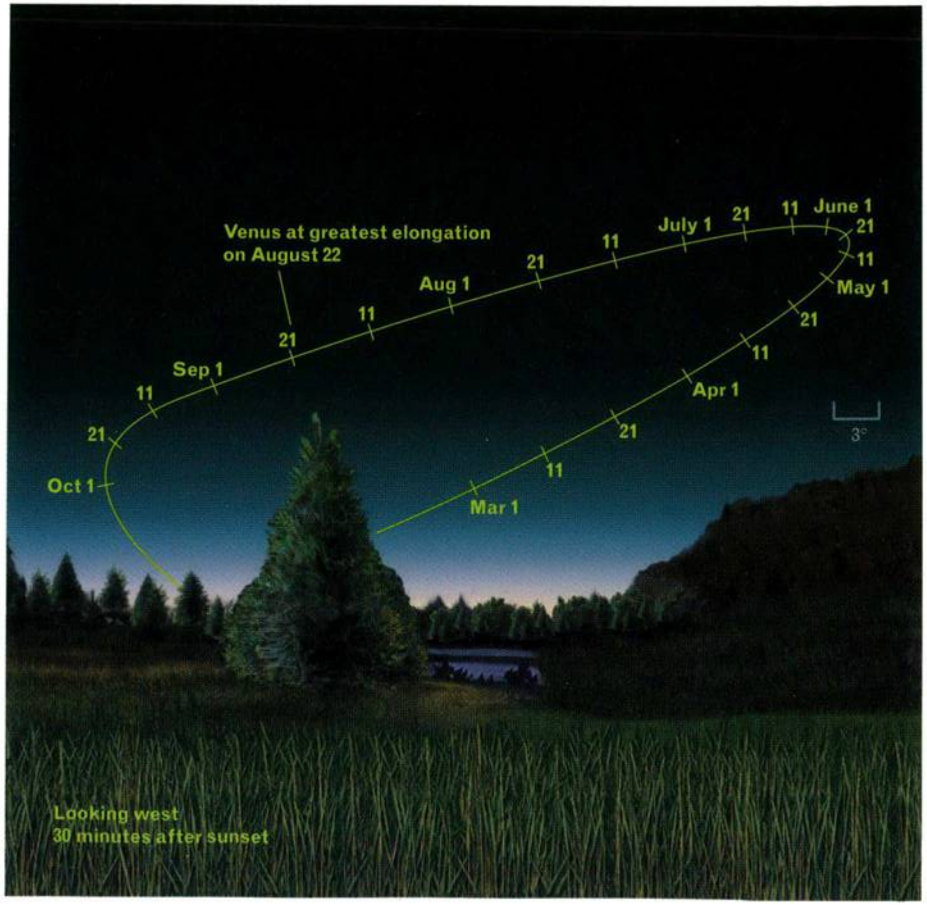
26 **8 A.M.**
Penumbral lunar eclipse

27 **3 A.M.**
Mercury is in inferior conjunction

JUN

Venus's Dazzling Dance

Venus ranks as the brightest of all the planets, and on June evenings it appears close to Jupiter, the largest of the planets. (Jupiter ranks second on the brightness list, adding to the evening scene.) The highly reflective, solid cloud deck of Venus, which hides all surface features below, efficiently mirrors sunlight. So whenever the planet is visible, either as a morning "star" or evening "star," it appears dazzling.

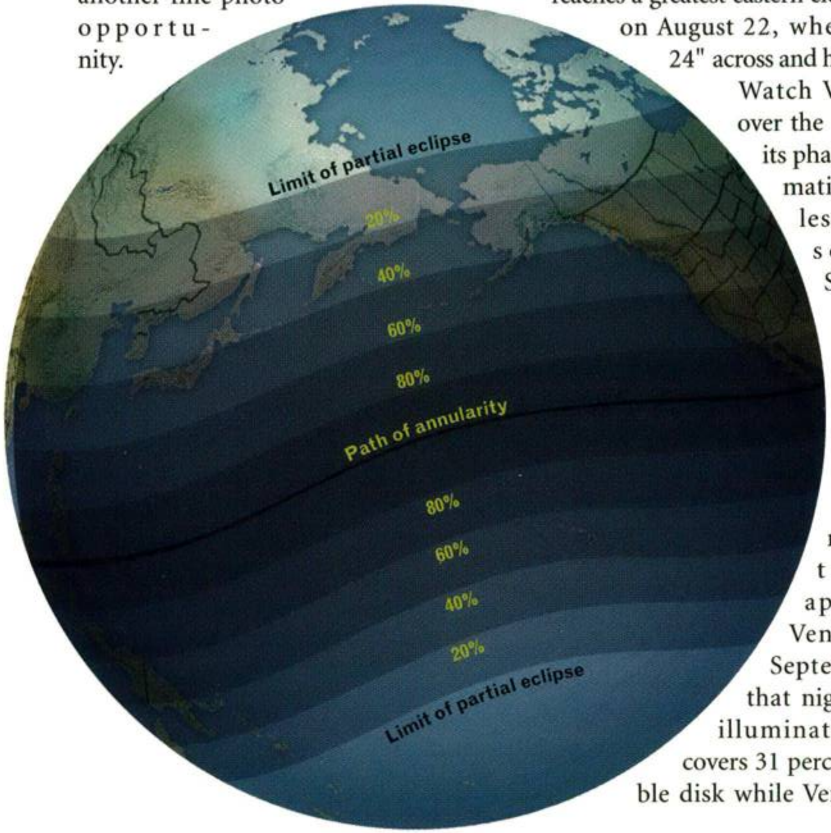


This year, because of the orbital dance that each planet makes around the sun, Venus has close conjunctions with Mercury, Mars, Jupiter, and Saturn. Following May's spectacular planetary line-up, Venus continues to brighten and appears in a darker sky as it climbs higher with each passing evening.

As June opens, only 2° separate Venus and Jupiter. The pair stands just below the bright stars Castor and Pollux in Gemini. On June 3 they appear slightly closer — 1.6° or three moon-widths apart — their closest for the year. This brilliant pairing of the brightest and the largest planet in the solar system proves stunning as they set slowly in the northwest. Venus shines at magnitude –4.0; at magnitude –1.9, Jupiter appears some seven times fainter. Through a telescope, Venus exhibits an 80-percent-lit phase and a tiny 13"-diameter disk. Jupiter, while much farther from Earth, has an apparent size of 33", some two-and-a-half times that of Venus.

During the remainder of June, Jupiter continues to slip into the sun's glow, while Venus climbs higher. A slender crescent moon passes 2° above Venus on June 13 — a great opportunity for all photographers out there. The drama continues on June 20, when Venus slides through the northern part of the Beehive star cluster (M44) in Cancer the Crab.

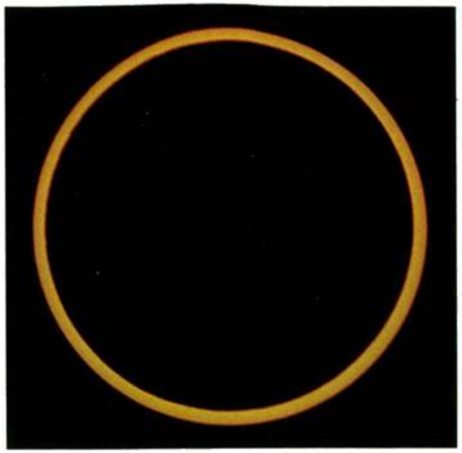
Venus glides 1° north of Regulus, the brightest star in Leo the Lion, on July 10. In a telescope it displays a disk that measures 16" across and appears two-thirds lit. Three days later, the crescent moon joins the scene, providing yet another fine photo opportunity.



As Venus slides along the ecliptic it dips south in declination, resulting in the planet appearing farther south of west each night. The angle of the ecliptic to the western horizon grows shallower as summer progresses, so Venus's altitude as seen from the Northern Hemisphere drops even as the planet moves farther from the sun. It reaches a greatest eastern elongation of 46° on August 22, when it appears 24" across and half-lit.

Watch Venus closely over the next month as its phase shrinks dramatically. It skims less than 1° south of Spica in Virgo on August 31, and through a telescope it appears 43 percent illuminated. The moon matches the telescopic appearance of Venus around September 11. On that night the moon's illuminated surface covers 31 percent of the visible disk while Venus, visible to the moon's lower right, shows a 36-percent-lit crescent. By September 30 Venus appears just 22 percent lit. Throughout this period, the apparent size of Venus has been increasing (up to 43" on the 30th) as the planet comes closer to Earth.

Venus passes into the morning sky following its inferior conjunction with the sun on October 31. A month later, on December 1, it meets with Mars and a waning crescent moon. All three lie within a 2° circle, providing a fitting end to a dramatic year of events with Venus.


Jill Foster and Brian Kimball

A Ringed Sun in Mexico

The first solar eclipse of 2002 arrives on June 10/11 and, for the third year in a row, observers across a good portion of North America will witness a partial eclipse. Die-hard eclipse chasers won't be satisfied with a look at the partially eclipsed sun, however, and will want to journey to the path of maximum eclipse. Unfortunately, the moon lies too far away from Earth to completely cover the sun. So at mideclipse, rather than seeing the corona as in a total eclipse, a bright ring of the solar photosphere remains visible. This ring of light, or "annulus," gives the eclipse its name.

The moon's shadow first hits Earth along the north coast of Sulawesi in Indonesia. After touching a few more Indonesian islands, the path of annularity tracks across the Pacific Ocean, making landfall only in Saipan and Tinian in the Northern Mariana Islands. From there, the shadow falls on no populated area until it hits the Pacific Coast of Mexico about 20 miles south of Puerto Vallarta, at sunset on the 10th. On the center line, observers will see the ring of fire on the horizon for just over a minute.

For those in the rest of North America (except the northeastern part), a partial eclipse can be seen. The eclipse will be better the farther west you live, where it occurs earlier in the afternoon and thus higher in the sky, and farther south, where the moon covers a greater percentage of the sun's disk. As with any non-total eclipse, you must use proper eye protection to view this eclipse.

S	M	T	W	T	F	S
						1
◐	3	4	5	6	7	8
9	○	11	12	13	14	15
16	◑	18	19	20	21	22
23/30	●	25	26	27	28	29

EDT

3 **2 P.M.**
Venus passes 1.6° north of Jupiter (evening)

7 **1 A.M.**
Pluto is at opposition

9 **7 A.M.**
Saturn is in conjunction with the sun
10 A.M.
The moon passes 3° north of Mercury
4 P.M.
Venus passes 5° south of Pollux (evening)

10 **8 P.M.**
Annular solar eclipse

12 **8 A.M.**
The moon passes 0.9° north of Mars
midnight
The moon passes 2° north of Jupiter

13 **5 P.M.**
The moon passes 1.5° north of Venus

21 **9 A.M.**
Solstice (northern summer/southern winter begins)
11 A.M.
Mercury is at greatest western elongation (23°, morning)

24 **6 P.M.**
Penumbral lunar eclipse

JUL

Hunt the Outermost Planet

Mysterious and alluring, Pluto beckons to backyard observers around the globe. Maybe it's because no human eye, or spacecraft, has gazed upon this world up close. Our imaginations can run wild as we envision an alien landscape bathed in the soft glow of a distant sun.

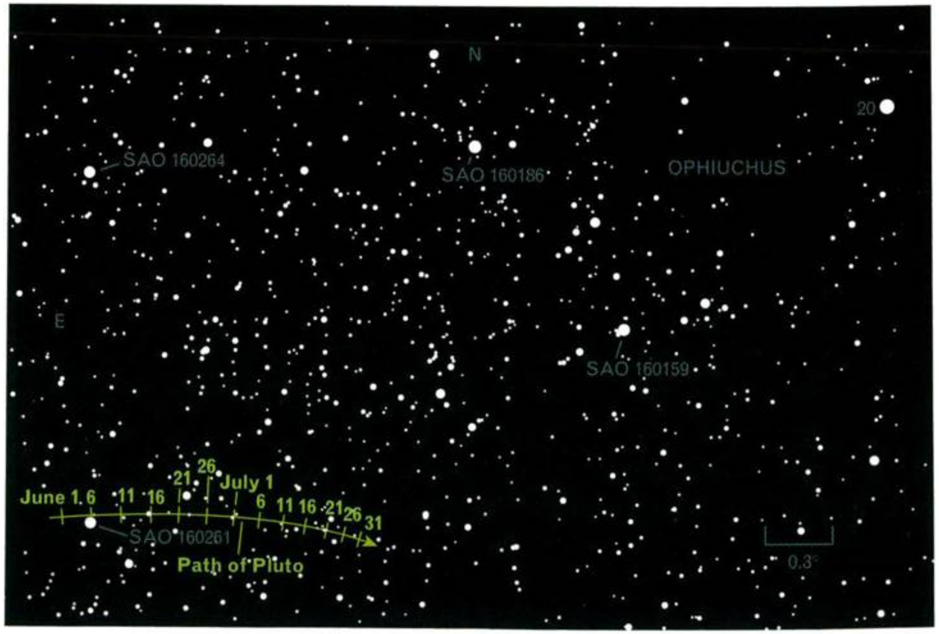
R. Albrecht (ESA/ESO) and NASA

Whatever the reason, few celestial objects appeal to the romance of observing as much as Pluto. You can rekindle that romance by bagging the solar system's most distant planet this summer, when it appears at its highest in the evening sky. All you need is the right equipment and the knowledge of when and where to look.

Pluto reached opposition, when it appeared opposite the sun in our sky, on June 6/7. But it lies so far from us that its distance — and thus brightness — varies little during the course of the year. To glimpse the feeble light of this 14th-magnitude object, you'll want to use an 8-inch or larger telescope.

Also choose an observing site that's far removed from the competing lights of the city and a time when the harsh glare of the moon won't interfere. That means from about last quarter phase to new moon, which this summer runs from approximately the 1st to the 10th of each month.

Throughout this period, Pluto treks slowly westward through southern Ophiuchus. To locate the planet, first find the 2.6-magnitude star Zeta (ζ) Ophiuchi. It lies 16° due north of 1st-magnitude Antares in Scorpius. It's also the middle star at the base of the large kite-shaped form of Ophiuchus, lying midway between Delta (δ) and Eta (η) Ophiuchi.



From Zeta, head 3° due east to the 5th-magnitude star 20 Ophiuchi. That star serves as the jumping-off point so you can star-hop to Pluto using the sky map above. The chart shows Pluto's position at 11 P.M. EDT (10 P.M. CDT, 9 P.M. MDT, and 8 P.M. PDT) during June and July. It includes stars down to magnitude 14.0, about 20 percent fainter than Pluto, so you should be able to discern the point of light that is Pluto from the background stars. To confirm your sighting, however, sketch the field of view in your telescope and return to the same field a night or two later. The "star" that has shifted position is Pluto.

Exploring the Summer Sky

The richness of the summer sky is exemplified by the splendor of the Milky Way. Stretching from the northern horizon in Perseus, through the cross-shaped constellation Cygnus overhead, and down to Sagittarius in the south, the Milky Way is packed with riches. These riches include star clusters, nebulae, double stars, and variable stars.

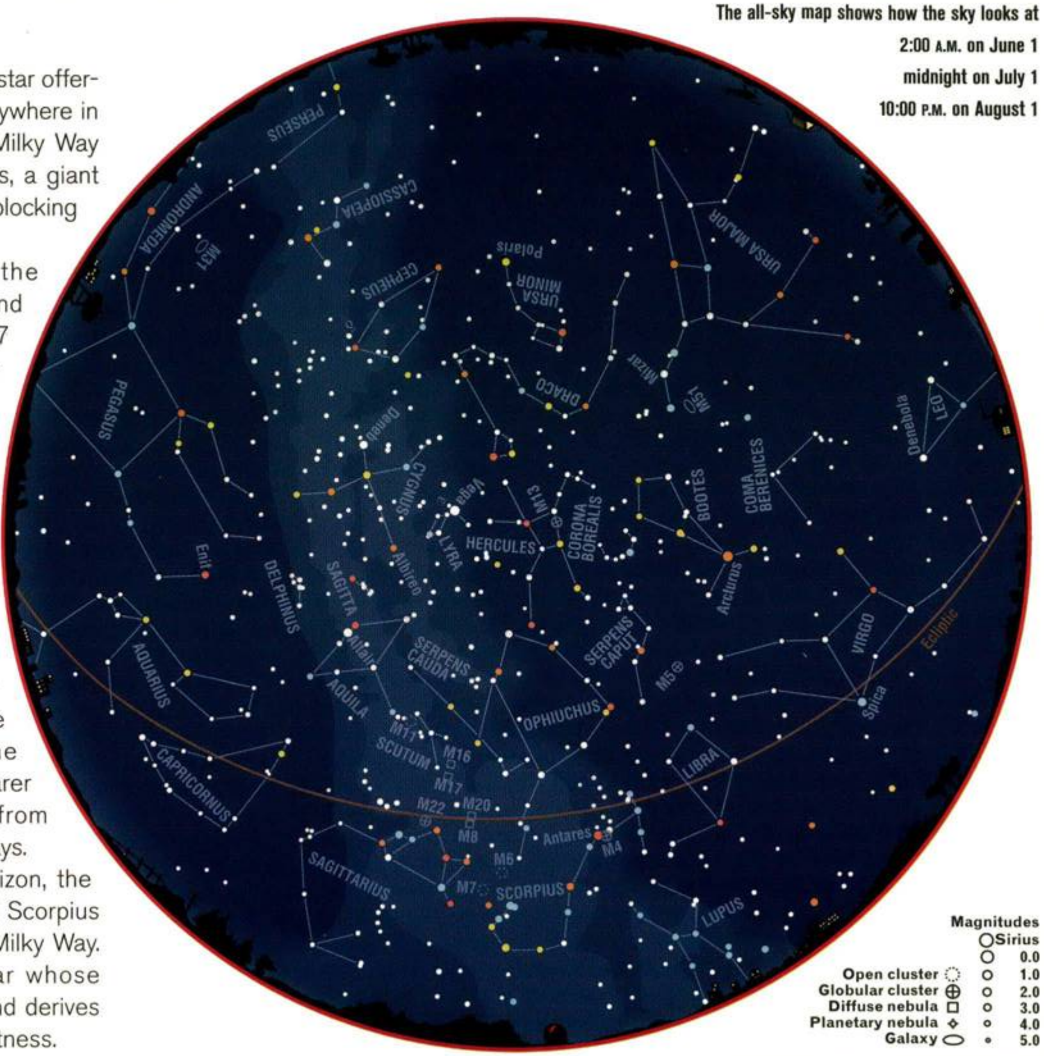
Let's start with the Big Dipper, our stellar signpost, which now lies in the northwest with its handle still pointing toward Arcturus. High overhead and the first star to appear after sunset is Vega in Lyra the Harp. Vega forms one corner of the summer triangle, a familiar asterism of three stars. Near Vega is the famous double-double, Epsilon (ε) Lyrae. Two 5th-magnitude stars lie just over 3' apart and can be split in binoculars. Each of these two stars is also double, but you need a telescope to split them.

To the east of Vega lies the triangle's second star: Deneb in Cygnus the Swan (some see a cross in this pattern). Deneb marks the tail of this graceful bird, the cross represents its outstretched wings, and the base of the cross denotes its head, which is marked by the incomparable double star Albireo – a match of a 3rd-magnitude yellow star and a 5th-magnitude blue star offering the finest color contrast anywhere in the sky. Also notice that the Milky Way splits into two parts in Cygnus, a giant rift caused by interstellar dust blocking starlight from beyond.

Altair, the third star of the summer triangle, is the second brightest of the three. Lying 17 light-years away, it's the brightest star in Aquila the Eagle.

Frequently overlooked to the north of Deneb lies the constellation Cepheus the King. Shaped rather like a bishop's hat, the southern corner of Cepheus is marked by a compact triangle of stars including Delta (δ) Cephei. This famous star is the prototype of the Cepheid variable stars used to determine the distances to some of the nearer galaxies. It varies regularly from magnitude 3.6 to 4.3 in 5.37 days.

Hugging the southern horizon, the constellations Sagittarius and Scorpius lie in the thickest part of the Milky Way. Antares is a supergiant star whose name means "rival of Mars" and derives from its similar color and brightness.


PERSEUS
ANDROMEDA
M31
CASSIOPEIA
CEPHEUS
Polaris
URSA MINOR
URSA MAJOR
DRACO
Mizar
M51
Denebola
LEO
PEGASUS
Deneb
CYGNUS
Vega
LYRA
M13
HERCULES
CORONA BOREALIS
BOOTES
COMA BERENICES
Enif
DELPHINUS
SAGITTA
Albireo
Arcturus
VIRGO
Ecliptic
AQUARIUS
AQUILA
Altair
SERPENS CAUDA
SERPENS CAPUT
M5
OPHIUCHUS
Spica
M11
SCUTUM
M16
M17
M20
M22
M8
Antares
M4
LIBRA
CAPRICORNUS
SAGITTARIUS
M6
M7
SCORPIUS
LUPUS
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows how the sky looks at
2:00 A.M. on June 1
midnight on July 1
10:00 P.M. on August 1

S	M	T	W	T	F	S
	1	◐	3	4	5	6
7	8	9	○	11	12	13
14	15	16	◑	18	19	20
21	22	23	●	25	26	27
28	29	30	31			

EDT

2 **7 A.M.**
Mercury passes 0.2° south of Saturn (morning)

3 **2 A.M.**
Mars passes 0.8° north of Jupiter (evening)

4 **1 P.M.**
Mars passes 6° south of Pollux (evening)

8 **9 A.M.**
The moon passes 1.7° north of Saturn

10 **6 A.M.**
Venus passes 1.1° north of Regulus (evening)

13 **8 A.M.**
The moon passes 4° north of Venus

19 **9 P.M.**
Jupiter is in conjunction with the sun

20 **10 P.M.**
Mercury is in superior conjunction

24 **7 P.M.**
The moon passes 4° south of Neptune

26 **5 A.M.**
The moon passes 4° south of Uranus

AUG

Perseids Return to Glory

Wishing upon a falling star is a popular pastime of young lovers, and on August 12 there will be plenty of opportunities for wishes. This date marks the peak of the dependable Perseid meteor shower, when shooting stars, or more correctly, meteors, appear to fall from the sky. This year's display promises to be a good one because moonlight will not interfere with the shower.

Meteors, of course, have little to do with stars. They are particles of dust in orbit around the sun that occasionally run into Earth. When they do so they make a fiery plunge into our atmosphere, burning up from the heat generated by friction with the air. Perseid meteors enter the atmosphere moving at speeds of 37 miles per second.

Many meteors occur randomly, generating about seven meteors per hour on any given night anywhere in the world. Occasionally, however, Earth runs into a stream of meteors, a region where interplanetary dust exists at a higher density. We now understand these trails to be cometary debris from earlier passes of comets in the same orbit. Rather like a jet leaves a vapor trail in our skies, a comet leaves a trail of debris behind it as ices and dust boil off its nucleus.

The Perseid meteor shower is tied to material spewed out by Comet 109P/Swift-Tuttle during its frequent visits in years gone by. The comet's last incursion into the inner solar system came in 1992, and in the years around that time observers noted increased activity. However, material from the comet is well distributed around the orbit, providing an annual spectacle that is more predictable than most showers.

Wally Pacholka

This year's maximum arrives at the time of a first quarter moon, which is good news. Moonlight significantly interferes with meteor watching. The large majority of Perseid meteors are seen in the early morning hours when Perseus — the constellation they appear to radiate from — is rising higher in the sky. The moon will then be gone from the sky, setting the stage for a good view. The only other variable is the weather; we can only hope to get clear skies.

Watch after midnight when Earth is traveling directly into the dust stream,

METEOR SHOWERS FOR 2002

Name	Peak Date	Moon's Phase	Prospects
Quadrantids	January 3	Waning gibbous	Poor
Lyrids	April 22	Waxing gibbous	Fair
Eta Aquarids	May 5	Last quarter	Poor
Perseids	August 12	Waxing crescent	Excellent
Orionids	October 21	Full moon	Poor
Leonids	November 18	Waxing gibbous	Fair
Geminids	December 14	Waxing gibbous	Fair

and find an observing site located well away from any streetlights and that provides a clear view of most of the sky. It's always a good idea to wrap up warmly and take along a sleeping bag and a hot drink, because temperatures can fall pretty low in the early morning hours.

On the peak night of August 12/13, you can expect to see about 50 meteors per hour. On the nights either side of maximum, rates are about one-fifth of that number. The Perseids can generate a few fireballs, especially prior to dawn. So keep on wishing, and enjoy one of the year's finest nighttime spectacles.

The Return of Comet Wirtanen

One of the best periodic comets scheduled to return this year goes by the name 46P/Wirtanen. Discovered in January 1948 by Lick Observatory astronomer Carl Wirtanen, it has been recovered at every return since, except for the one in 1980. Shortly after that return, the comet passed close to Jupiter, and the planet's immense gravity perturbed the comet's orbit. It now returns to the inner solar system every 5.4 years and makes its closest approach to the sun, a point called perihelion, just outside Earth's orbit.

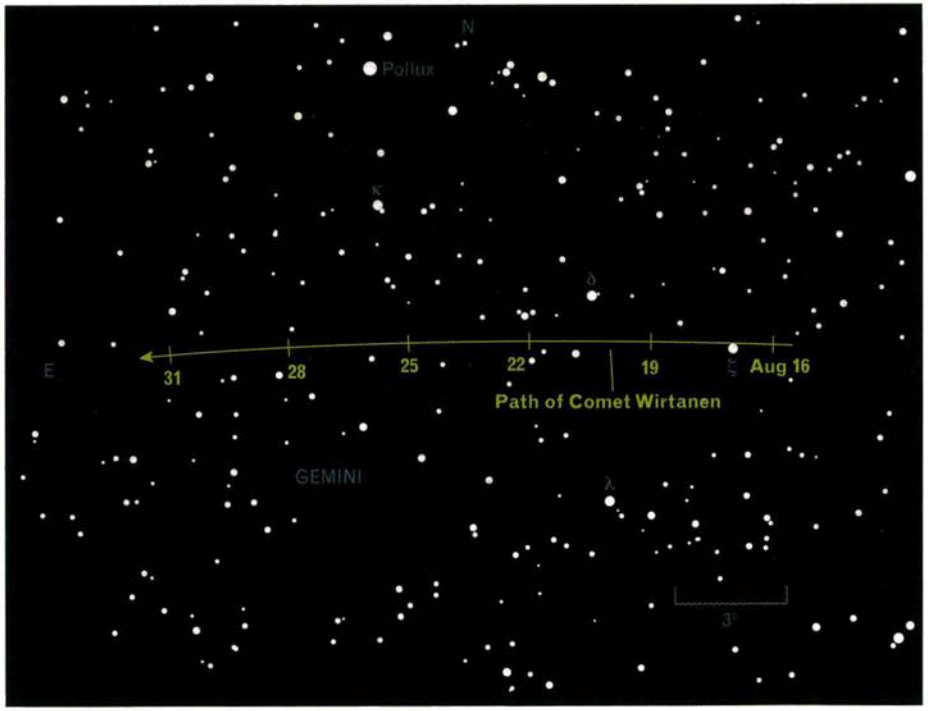
Comet 46P/Wirtanen should peak at about 10th magnitude around the time it reaches perihelion on August 26. At the time, it will be visible in the morning sky, fairly low in the east as morning twilight commences. Throughout the second half of August, when it glows brightest, it travels eastward through the western half of Gemini.

It passes less than 1° north of the 4th-magnitude star Zeta (ζ) Geminorum on the morning of August 17 and less than 2° south of the similarly bright Delta (δ) Gem on the 20th. By the time of perihelion, it lies 7° due south of 1st-magnitude Pollux, Gemini's brightest star.

To locate 46P/Wirtanen, use the sky map at right to zero in on the correct area of sky. The chart shows the comet's position at 4 A.M. EDT (3 A.M. CDT, 2 A.M. MDT, and 1 A.M. PDT). Then search for a fuzzy blob, looking much like a distant galaxy, in the eyepiece of your telescope.

The fuzzy appearance of the comet stems from its physical nature. When located far from the sun, a comet exists as a cold, inert mixture of ice and dust. The ices include the familiar water ice as well as more exotic ones like frozen carbon dioxide (dry ice) and carbon monoxide. For a comet like 46P/Wirtanen, this nucleus measures only a mile or so across. (Hale-Bopp, on the other hand, had a diameter of 25 miles.)

As a comet approaches the sun, however, its nucleus warms and the ices start to turn directly into gas, releasing trapped dust particles in the process. The expanding cloud of gas and dust forms the "coma," which can stretch 100,000 miles or more and gives the comet its fuzzy appearance. The solar wind and pressure from sunlight push the gas and dust, respectively, away from the comet, forming the comet's often glorious tails.



S	M	T	W	T	F	S
				◐	2	3
4	5	6	7	○	9	10
11	12	13	14	◑	16	17
18	19	20	21	●	23	24
25	26	27	28	29	◐	31

EDT

1 **9 P.M.**
Neptune is at opposition

4 **midnight**
The moon passes 2° north of Saturn

5 **midnight**
Mercury passes 0.9° north of Regulus (evening)

9 **9 P.M.**
The moon passes 4° north of Mercury

10 **6 P.M.**
Mars is in conjunction with the sun

11 **6 P.M.**
The moon passes 6° north of Venus

12 **8 A.M.**
Asteroid Pallas is at opposition
Perseid meteor shower peaks

19 **9 P.M.**
Uranus is at opposition

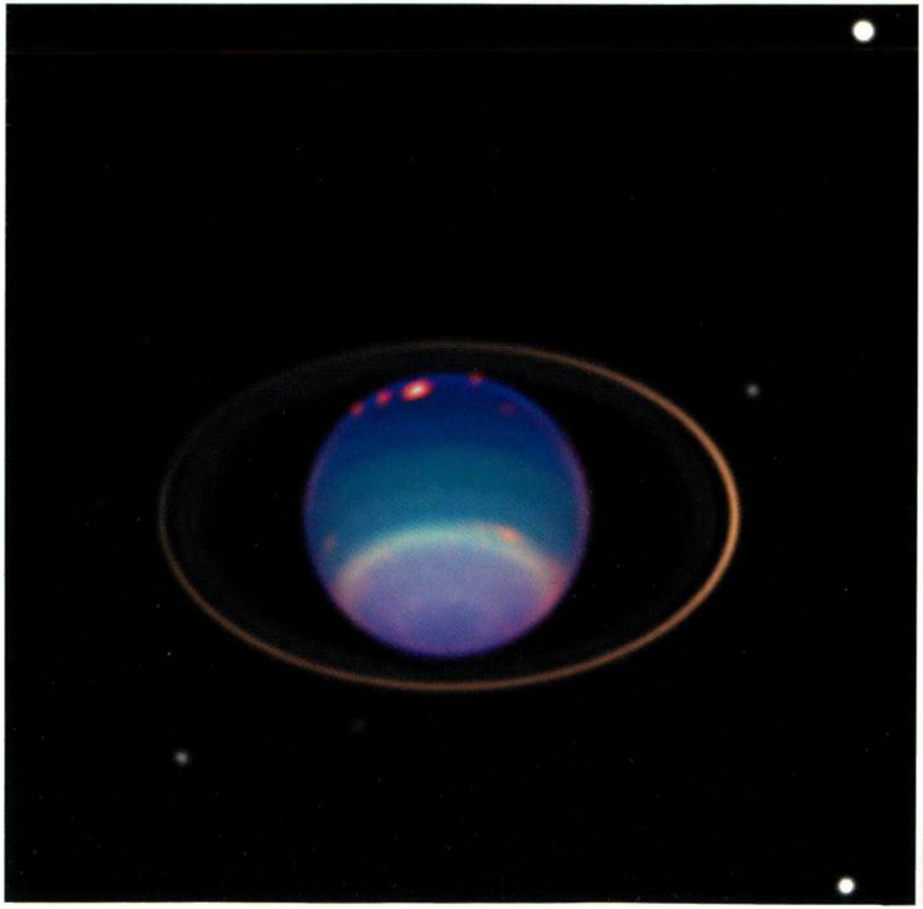
20 **midnight**
The moon passes 4° south of Neptune

22 **9 A.M.**
Venus is at greatest eastern elongation (46°, evening)
10 A.M.
The moon passes 4° south of Neptune

SEP

Uranus and Neptune Drift Apart

Sixteen days separated the oppositions of Uranus and Neptune last year. This year, with Uranus traveling along its orbit at a faster pace than its more distant cousin, the gap between their respective oppositions has expanded to 18 days.


NASA/STScI

NASA/STScI

Neptune, the eighth planet from the sun, ponders along its orbit slowly and reaches opposition on August 1/2. You can spot it with binoculars if you know where to look. Throughout the summer it glows at 8th magnitude and lies 29 astronomical units from Earth (1 AU equals about 93 million miles). At this distance, the giant planet, four times the diameter of Earth, appears as a tiny blue-gray disk only 2.3" across.

Neptune remains in the dim constellation of Capricornus the Sea-Goat, and the best way to find it is as follows. Locate Theta (θ) Capricorni, a 4th-magnitude star in the northern part of the constellation. Then find 19 Cap, a 6th-magnitude star 2.7° west-southwest of Theta, in your finderscope and center that star in a low-power eyepiece. With your drive system off, allow the sky to drift for an amount of time depending on the date you observe. On August 1, wait 6.5 minutes; on August 15, wait 8 minutes; and on August 31, wait 9.5 minutes. For dates in between, interpolate for the correct time. The difference in duration is due to Neptune's gradual western, or retrograde, motion against the background stars.

Uranus reaches opposition on August 19/20 and straddles the border between Aquarius and Capricornus. It's easier to find because it shines much brighter than Neptune at magnitude 5.7. Although Uranus is nearly the same size as Neptune, it's 10 AU (930 million miles) closer to Earth. This makes Uranus's disk larger in a telescope, spanning 3.7".

As August opens, Uranus lies 1.7° northwest of the 4.3-magnitude star Iota (ι) Aquarii. During August, the planet wanders westward against the stars and by month's end stands 3° northeast of 3rd-magnitude Delta (δ) Cap, the star at the eastern end of the broad triangle that forms the shape of Capricornus. Compare the color of Delta to that of Uranus. The star shines white and contrasts nicely with the blue-green hue of the solar system's seventh planet.

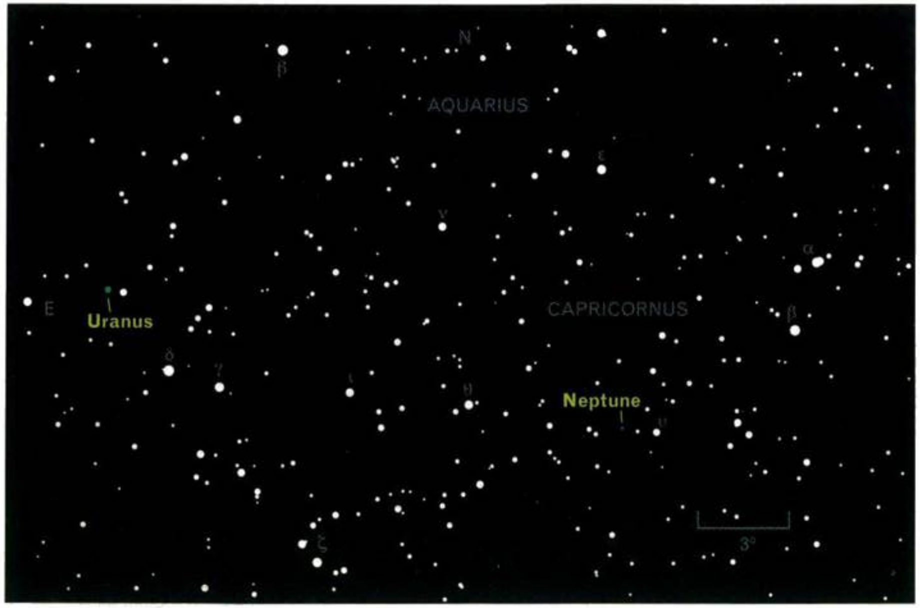
Although backyard telescopes don't show any surface detail on either of the two distant giant planets, simply spotting them can be memorable. Uranus was discovered in 1781 and Neptune in 1846. By finding them for yourself, you join the surprisingly small number of people on our planet, following Sir William Herschel (discoverer of Uranus) and Johann G. Galle (the first to spot Neptune), to ever see these planets.

Auroral Activity Heats Up

Although the maximum of the solar cycle has just passed, with the number of sunspots apparently peaking during 2001, the pace of auroral activity should remain high throughout 2002. The number and intensity of aurorae often peak a year or two after solar max, so it will be worth keeping your eye to the sky.

Of course, solar activity and aurorae are intimately related. It's the active sun, rife with sunspots, flares, and coronal mass ejections, that spews out charged particles into the solar system. When Earth finds itself in the way, the particles get funneled into the polar regions by our planet's magnetic field. That's why aurorae are much more common in the polar regions than at mid-latitudes, though at times of high solar activity, they can reach down to lower latitudes.

The various colors of the aurora arise from the atoms and molecules the charged particles hit. Particles that penetrate to within 60 miles of Earth's surface excite oxygen to glow green. More energetic particles dig deeper and cause nitrogen to glow red. Nitrogen, the most abundant constituent of the atmosphere, also gives rise to blue and purple aurorae.



Ales Kolar

S	M	T	W	T	F	S
1	2	3	4	5	○	7
8	9	10	11	12	◑	14
15	16	17	18	19	20	●
22	23	24	25	26	27	28
◐	30					

EDT

1 **2 A.M.**
Venus passes 0.9° south of Spica (evening)
6 A.M.
Mercury is at greatest eastern elongation (27°, evening)
1 P.M.
The moon passes 2° north of Saturn

4 **9 A.M.**
The moon passes 4° north of Jupiter

9 **10 P.M.**
The moon passes 8° north of Venus

17 **5 A.M.**
The moon passes 4° south of Neptune

18 **2 P.M.**
The moon passes 4° south of Uranus

23 **1 A.M.**
Equinox (northern autumn/southern spring begins)

26 **7 A.M.**
Venus is at greatest brilliancy (magnitude −4.6)

27 **3 P.M.**
Mercury is in inferior conjunction

28 **11 P.M.**
The moon passes 3° north of Saturn

OCT

Ceres Comes into View

More than two hundred years have passed since the discovery of the first minor planet, or asteroid. Giuseppe Piazzi found Ceres in 1801, lurking in the large gap between the orbits of Mars and Jupiter. Since that time, more than ten thousand have been discovered.

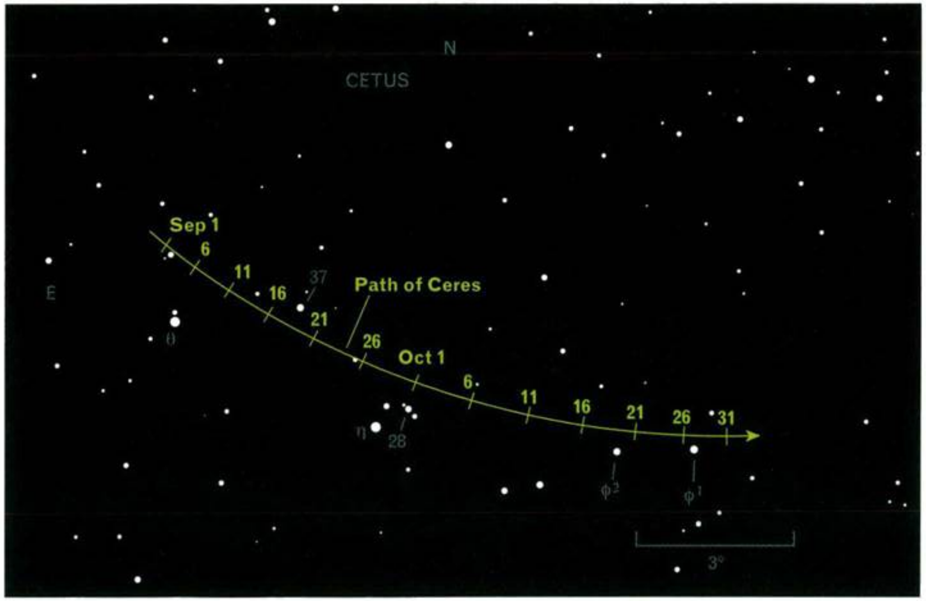
With the advent of the CCD camera, many amateur astronomers are adding to the total each month. Most asteroids remain too dim to be seen with backyard scopes, but five come within easy reach during 2002. Asteroids 1 Ceres, 3 Juno, 7 Iris, 15 Eunomia, and 18 Melpomene all make tempting targets this year.

These five asteroids can be followed using either binoculars or a small telescope. The easiest method to spot one is to locate the star field surrounding it and make a detailed drawing of what you see. On a subsequent evening, preferably the following night, make another drawing, and the asteroid will give up its identity by its apparent motion relative to the "fixed" stars.

The brightest asteroid to reach opposition this year is none other than Ceres. It lies opposite the sun in the sky on October 4, when it peaks in brightness at magnitude 7.6 among the stars of Cetus and lies within easy binocular range. Use the map at right to find it anytime during September or October. It will probably be simplest to find around September 27, when it passes just 1° north of the 3.5-magnitude star Eta (η) Ceti.

By coincidence, Melpomene comes to opposition on the 27th. It also lies in Cetus and, at magnitude 7.8, is just a hair fainter than Ceres. Look for it 10° due west of Ceres, or 3° southeast of the 3.6-magnitude star Iota (ι) Ceti.

Late summer and early autumn seem to be prime time for asteroid hunting this year, as both Iris and Eunomia also reach opposition then. Only Juno breaks the spell with its winter appearance.



Many other asteroids come within reach of amateur telescopes and binoculars during 2002. The brightest of all, 4 Vesta, doesn't come to opposition, but you can locate it quite easily in December, when it glows at magnitude 7.6 in western Virgo. It reaches opposition on March 26, 2003, shining at magnitude 5.9, just visible to the naked eye.

ASTEROIDS IN 2002

Asteroid	Opposition Date	Con.	Magnitude
1 Ceres	October 4	Cetus	7.6
3 Juno	February 10	Hydra	8.3
7 Iris	August 27	Aquarius	7.7
15 Eunomia	September 14	Pegasus	8.0
18 Melpomene	September 27	Cetus	7.8

Exploring the Autumn Sky

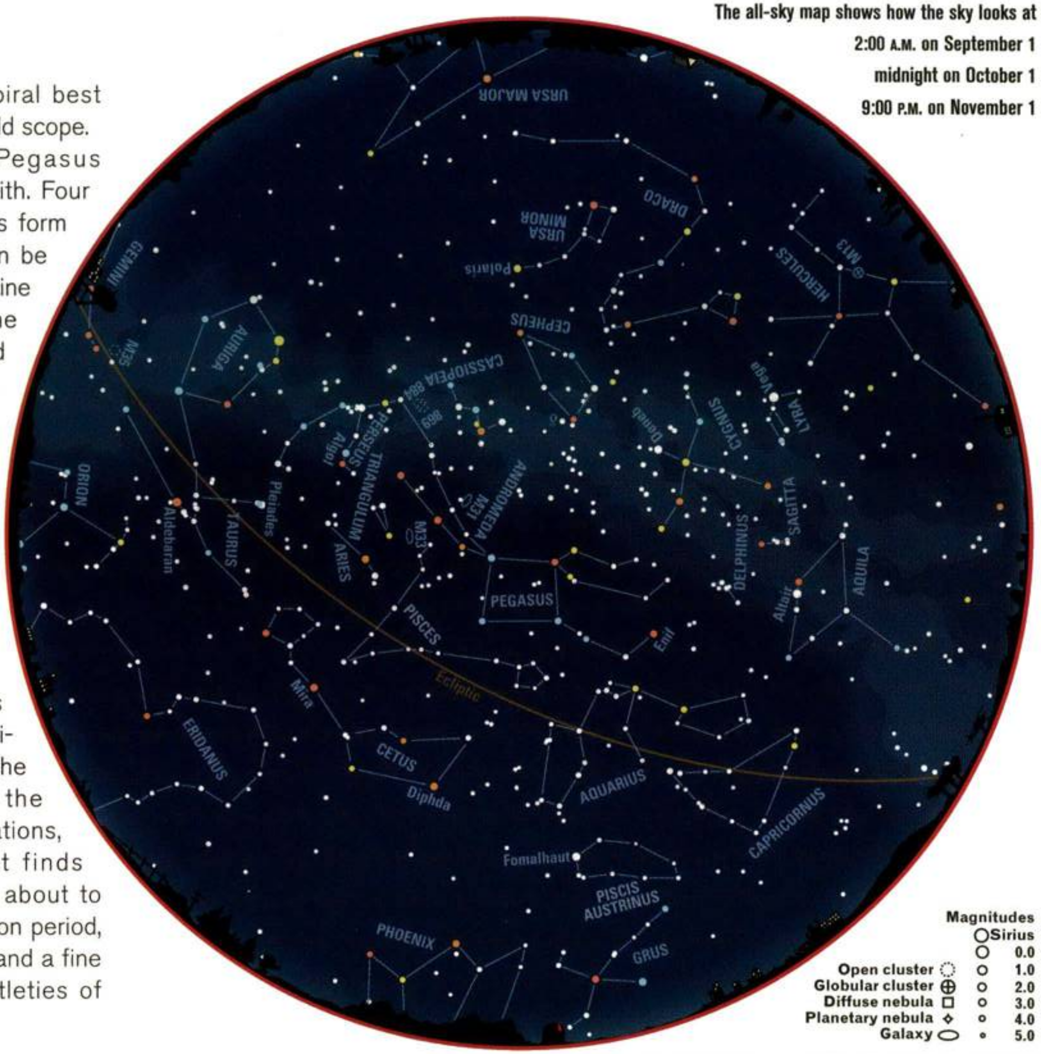
The cool nights of autumn are here to remind us that the chill of winter is not far off. Along with the cool air, the brilliant stars of the summer triangle descend in the west to be replaced with a rather bland-looking region of sky. But don't let initial appearances deceive you. Hidden in the fall sky are gems equal to those of summertime.

The Big Dipper swings low this season, and for parts of the southern United States it actually sets. Cassiopeia, a group of five bright stars in the form of a "W" or "M," reaches its culmination overhead, the same point the Dipper reached six months ago. To the east of Cassiopeia, Perseus rises high. Nestled between these two groups is the wonderful Double Cluster – NGCs 869 and 884 – a fantastic sight in binoculars or a low-power telescope.

Our view to the south of the Milky Way is a window out of the disk of our galaxy in the opposite direction to that visible in spring. This allows us to look at the Local Group of galaxies. Due south of Cassiopeia is the Andromeda Galaxy (M31), a 4th-magnitude smudge that passes overhead on November evenings. Farther south lies M33, a large, sprawling, face-on spiral best seen in binoculars or a rich-field scope.

The Great Square of Pegasus passes just south of the zenith. Four 2nd- and 3rd-magnitude stars form the square, but few stars can be seen inside of it. If you draw a line between the two stars on the right side of the square and extend it southward, you'll find 1st-magnitude Fomalhaut in Piscis Austrinus. Fomalhaut appears as the solitary bright star low in the south.

To the east of the square lies the Pleiades star cluster (M45), which reminds us of the upcoming winter. By late evening in October and early evening in December, Taurus and Orion are clear of the horizon and Gemini is rising in the northeast. In concert with the reappearing winter constellations, the view to the northwest finds summer's Cygnus and Lyra about to set. Autumn is a great transition period, both on Earth and in the sky, and a fine time to experience the subtleties of these constellations.


URSA MAJOR
DRACO
URSA MINOR
Polaris
CEPHEUS
HERCULES
M13
GEMINI
M35
AURIGA
CASSIOPEIA
884
869
PERSEUS
Algol
TRIANGULUM
ANDROMEDA
M31
M33
Deneb
CYGNUS
Vega
LYRA
SAGITTA
ORION
Aldebaran
TAURUS
Pleiades
ARIES
PEGASUS
DELPHINUS
Altair
AQUILA
PISCES
Enif
Ecliptic
Mira
ERIDANUS
CETUS
Diphda
AQUARIUS
CAPRICORNUS
Fomalhaut
PISCIS AUSTRINUS
PHOENIX
GRUS
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows how the sky looks at
2:00 A.M. on September 1
midnight on October 1
9:00 P.M. on November 1

S	M	T	W	T	F	S
		1	2	3	4	5
○	7	8	9	10	11	12
◑	14	15	16	17	18	19
20	●	22	23	24	25	26
27	28	◐	30	31		

EDT

2 **3 A.M.**
The moon passes 4° north of Jupiter

4 **4 A.M.**
Asteroid Ceres is at opposition
9 P.M.
The moon passes 4° north of Mars

8 **6 A.M.**
The moon passes 10° north of Venus

13 **4 A.M.**
Mercury is at greatest western elongation (18°, morning)

14 **10 A.M.**
The moon passes 5° south of Neptune

15 **6 P.M.**
The moon passes 4° south of Uranus

21 Orionid meteor shower peaks

26 **5 A.M.**
The moon passes 3° north of Saturn

27 **4 A.M.** EST
Mercury passes 4° north of Spica (morning)

29 **5 P.M.** EST
The moon passes 4° north of Jupiter

31 **7 A.M.** EST
Venus is in inferior conjunction

NOV

Meteors from the Lion's Lair

Historian R. M. Devens called the Leonid meteor shower of 1833 "one of the 100 most memorable events in U. S. history." Bostonians described its appearance as approaching that of a snowstorm. "A tempest of falling stars," wrote Agnes Clerke, a 19th-century popularizer of astronomy.

Oshin D. Zakarian

The Leonids rank as the most enigmatic major meteor shower. Most years the shower produces a trickle of perhaps a couple dozen meteors per hour. But every 33 years or so it generates a storm of such magnitude that counting the number is practically impossible. For a brief interval of a couple hours, meteors can fall at a rate as high as 100,000 per hour, or a few dozen per second. Compare that with August's famous Perseid meteor shower, when observers are lucky to see one meteor per minute.

No one can predict with certainty what the 2002 Leonids have in store for us. Casual observers might even think that the hoopla is over. After all, Comet 55P/Tempel-Tuttle — the comet whose debris gives rise to the meteors we see burning up in our atmosphere — returned to the inner solar system back in early 1998. Activity was high in 1999, when up to 3,700 Leonids per hour were seen over parts of the Middle East. But the 2000 shower produced at best just a few hundred meteors per hour.

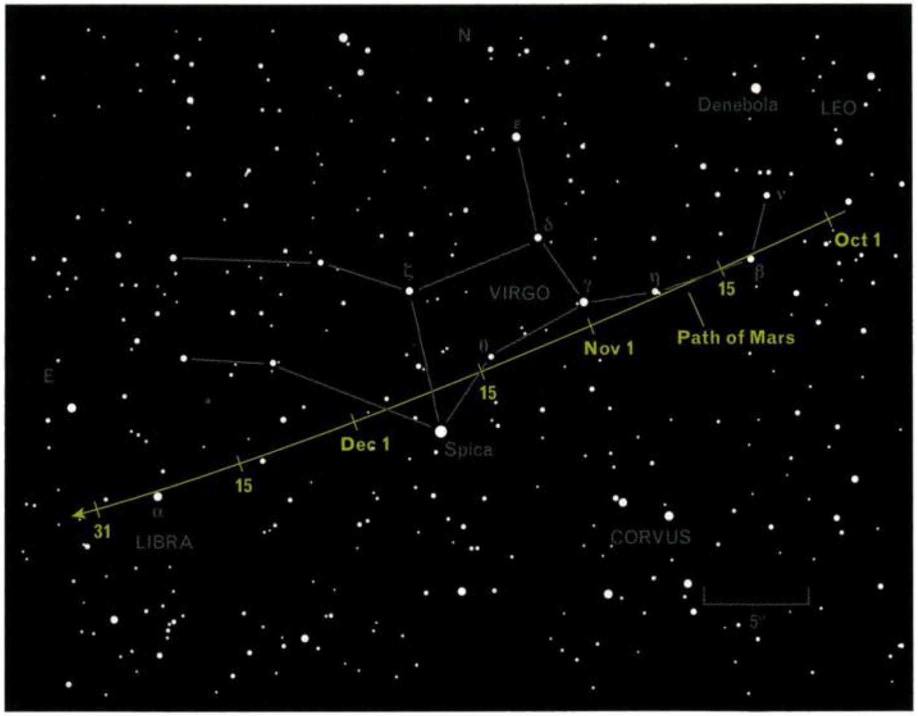
Still, hope is running high for 2002 because astronomers have gotten much better at predicting the Leonid shower. A sophisticated analysis of the dust trails left behind by 55P/Tempel-Tuttle allowed Robert McNaught of the Australian National University and David Asher of Armagh University in the United Kingdom to accurately forecast both the 1999 and 2000 showers. And they predict that 2002 could produce the biggest shower since 1966.

When the shower peaks on the mornings of November 18 and 19, up to 30,000 meteors per hour (nearly 10 per second) may be visible. Even better, the timing appears to favor North America on the morning of the 19th. The one drawback is that the moon will be a waxing gibbous at the time, which will wash out the fainter meteors. Still, the show could be one of the best of the new century.

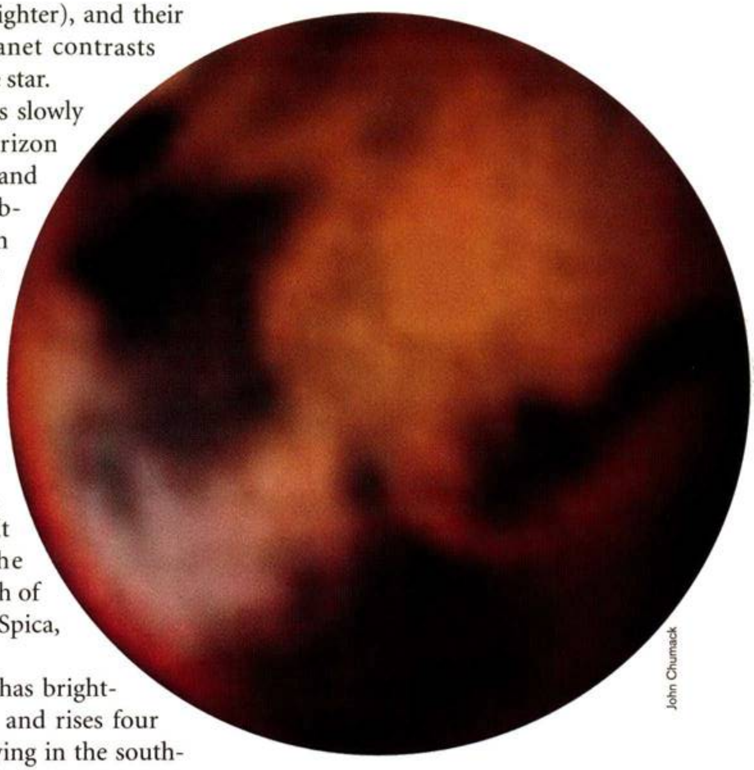
Prelude to a Martian Invasion

The year 2001 saw Mars put on its best show in more than a decade. Brilliant white polar caps, subtle dark markings, and major dust storms all provided Earthbound observers with memorable views. The stand-out appearance satisfied many backyard observers, who had waited so long for Mars's return to glory. Yet the 2001 apparition was mere prelude to what's in store.

This year begins with Mars glowing brightly in a rather bland region of the sky. The 0.8-magnitude planet lies fairly low in the southwest as the sky grows dark, overpowering the faint stars of its host constellation, Aquarius the Water-Bearer. Its only rival in this part of the sky is the 1st-magnitude star Fomalhaut in Piscis Austrinus, which lies directly below Mars. You can tell the two apart by their relative position, their brightness (Mars glows slightly brighter), and their color — the ruddy planet contrasts nicely with the icy white star.



Mars dims and drifts slowly toward the western horizon throughout the winter and spring, finally succumbing to the sun's glare in June. It then spends the next three months on the far side of the sun, out of sight from Earth. It returns to view in early October, rising in the east about an hour before the sun. For the rest of the year, it treks across Virgo the Maiden, passing 3° north of a slightly brighter star, Spica, in mid-November.


John Chumack

By year's end, Mars has brightened to magnitude 1.5 and rises four hours before the sun, lying in the southeastern sky before dawn among the stars of Libra the Scales. Still, that's a far cry from what 2003 holds in store. The quality of any Mars apparition depends largely on where the planet lies in its orbit as Earth catches up to it. Mars has an eccentric orbit that brings it 27 million miles closer to the sun at closest approach than when it is farthest away. If opposition arrives when Mars is near that closest point, or perihelion, the planet looms both large and bright.

That's what happens in 2003. Opposition comes on August 28, just one day after perihelion. Mars then shines at magnitude –2.9 and appears 25" across, both better than at any time in the past 1,000 years. It will again lie in Aquarius and be much higher in the sky than during 2001.

S	M	T	W	T	F	S
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10	◑	12	13	14	15	16
17	18	●	20	21	22	23
24	25	26	◐	28	29	30

EST

2 **1 P.M.**
The moon passes 4° north of Mars

10 **5 P.M.**
The moon passes 5° south of Neptune

11 **midnight**
The moon passes 5° south of Uranus

13 **midnight**
Mercury is in superior conjunction

18 Leonid meteor shower peaks

19 **9 P.M.**
Penumbral lunar eclipse

midnight
Mars passes 3° north of Spica (morning)

22 **7 A.M.**
The moon passes 3° north of Saturn

26 **2 A.M.**
The moon passes 4° north of Jupiter

DEC

Saturn: Big and Bright

Saturn's position as the most beautiful telescopic sight in the solar system goes unchallenged, with the rings adding a surreal impression that can't be beat. Youngsters are wide-eyed at their first view of the Ringed Planet, and no child should grow up never having seen Saturn in all its splendor. Saturn's position this year in Taurus the Bull adds to the spectacle because the constellation is so rich with two of the best open star clusters in the sky, the Pleiades and Hyades.

David Hanon

Saturn passes the latter half of the year climbing in altitude in the early morning sky, on its way to opposition on December 17. Curiously, Saturn spends most of September through November in the northernmost segment of Orion before its westward, or retrograde, motion carries it back into Taurus. On the night of opposition, Saturn glows a brilliant magnitude –0.3, easily outshining Aldebaran, the brightest star in Taurus. This is as bright as Saturn can get, a consequence of the rings now being tipped wide open to our view and the planet being near its closest point to the sun. At opposition, it's just 8.05 astronomical units (750 million miles) from Earth.

On the 17th, Saturn sits 1.2° northeast of 3rd-magnitude Zeta (ζ) Tauri, the star representing the southern horn of the bull. Saturn's nightly progression westward against the stars of Taurus will be obvious over the following week as it glides north of Zeta.

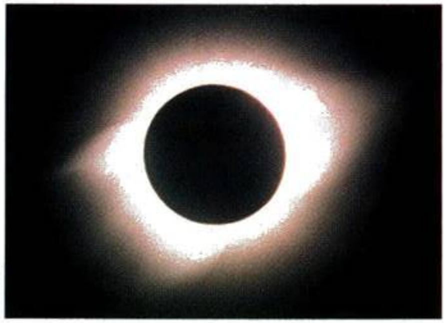
Keep your eye on Saturn as the year draws to a close. During the last week of December, the planet approaches the Crab Nebula (M1), the famous remnant of a supernova that exploded in 1054. By New Year's Eve, Saturn lies in the same low-power field of view as the Crab's glowing gases. Just two-thirds of a moon's diameter separates the two objects. On the night of January 4/5, 2003, Saturn actually passes through the northern part of the Crab. For a couple days on either side you might catch one of the planet's brighter moons crossing in front of the nebula. This unique event will certainly be one for the record books.

Compared with the rings and moons, Saturn's disk appears rather bland. It has a subtle, banded atmosphere, much like a severely muted Jupiter, but few other features are ever visible except in larger telescopes. However, large, short-lived, white spots have erupted from time to time. Such major storm systems are rare but intriguing, so keep on the lookout for such features.

Arguably the most interesting moon of Saturn turns out to be Iapetus. The moon shines at 10th magnitude when it lies west of the planet, five times brighter than its 12th-magnitude glow east of Saturn. The reason for this dramatic variability went unanswered until the Voyager spacecraft flew past the planet in the early 1980s. Images of Iapetus revealed that one hemisphere was as bright as snow and the other was covered in dark material the color of coal. Because Iapetus keeps the same face toward Saturn at all times, observers on Earth see the alternate bright and dark sides of the moon on each orbit.

The brightest moon of Saturn, Titan, shines at 8th magnitude. Tripod-mounted binoculars can reveal the moon, and any small telescope has no problem showing it. Titan is special because it is the only moon in the solar system to have a significant atmosphere. We know little of Titan's surface because of this permanent shroud. In just two years' time, in July 2004, this may all change. The Cassini-Huygens spacecraft, a joint NASA and European Space Agency mission, is on its way to Saturn, having successfully passed Jupiter in December 2000. If communications problems between the spacecraft and the Huygens probe are solved, the probe will drop through the atmosphere of Titan and, for the first time in history, we will see its surface.

Until that time, we can spend many hours at the telescope marveling at the Ringed Planet from a distance. It's a sight that you'll never tire of seeing.


Phil Brick

Another December Eclipse

For the third year in a row, December brings with it a solar eclipse. Unfortunately, this one won't be visible at all from the United States. But for those who like to travel, it does offer totality for people in southern Africa and Australia.

The second total solar eclipse of the new century begins in the eastern Atlantic Ocean on the morning of December 4, off the coast of Africa just south of the equator. The moon's umbral shadow first makes landfall along the coast of central Angola — the exact same area that saw totality just 18 months earlier. (An individual location on Earth's globe sees totality on average once every 300 years, so the residents of Angola are sitting in eclipse heaven.)

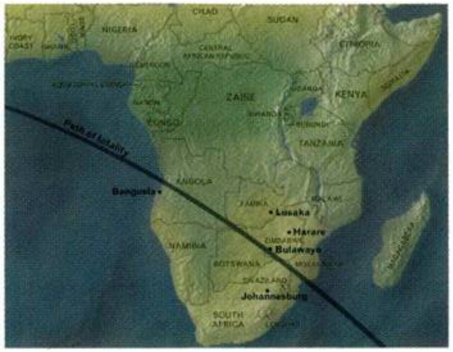
From there the track of totality heads southeast across Angola, crossing eastern Namibia and then hugging the border between Zimbabwe and Botswana, passing just south of the city of Bulawayo. The eclipse path then nips northern South Africa and southern Mozambique before heading into the Indian Ocean.

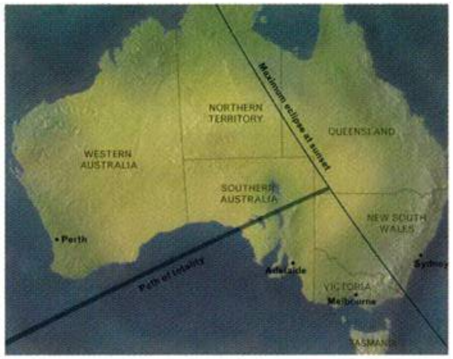
The length of totality increases from just under a minute in western Angola to about 1 minute and 30 seconds in Mozambique. Unfortunately, the weather prospects in Africa don't look great. By December southern Africa is into its annual wet season and cloudy skies are the rule along much of the track. The temperatures, humidities, and mosquitoes also run high at this time of year.

After crossing the Indian Ocean — where the eclipse reaches its maximum of 2 minutes and 4 seconds and the path grows to 54 miles across — the moon's shadow makes a final landfall in southern Australia, northwest of Adelaide. The town of Ceduna lies right on the center line and experiences a rather brief totality of 33 seconds. The sun then lies just 9° above the western horizon and sets into the ocean while still partially eclipsed. The shadow continues inland for a ways before leaving Earth in southwestern Queensland.

The weather prospects in Australia appear much better than in Africa. At Ceduna, December rainfall averages less than an inch and only three December days experience precipitation. It should be warm in Australia as well, with the Southern Hemisphere's summer almost ready to begin. Average highs in Ceduna run about 80° F while overnight lows dip only to about 60° F.

Australia promises exquisite views of fiery red prominences, a ghostly corona, and twilight hues circling the horizon. It should be a great adventure for those who venture into the path of totality.





EST

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8	9	10	◑	12	13	14
15	16	17	18	●	20	21
22	23	24	25	◐	27	28
29	30	31				

1 **5 A.M.**
The moon passes 3° north of Mars
8 A.M.
The moon passes 2° north of Venus

4 **3 A.M.**
Total solar eclipse

6 **8 P.M.**
Venus is at greatest brilliancy (magnitude –4.7)

14 Geminid meteor shower peaks

17 **noon**
Saturn is at opposition

19 **10 A.M.**
The moon passes 3° north of Saturn

21 **8 P.M.**
Solstice (northern winter/southern summer begins)

23 **7 A.M.**
The moon passes 4° north of Jupiter

25 **midnight**
Mercury is at greatest eastern elongation (20°, evening)

29 **8 P.M.**
The moon passes 1.2° north of Mars

30 **4 A.M.**
The moon passes 2° south of Venus

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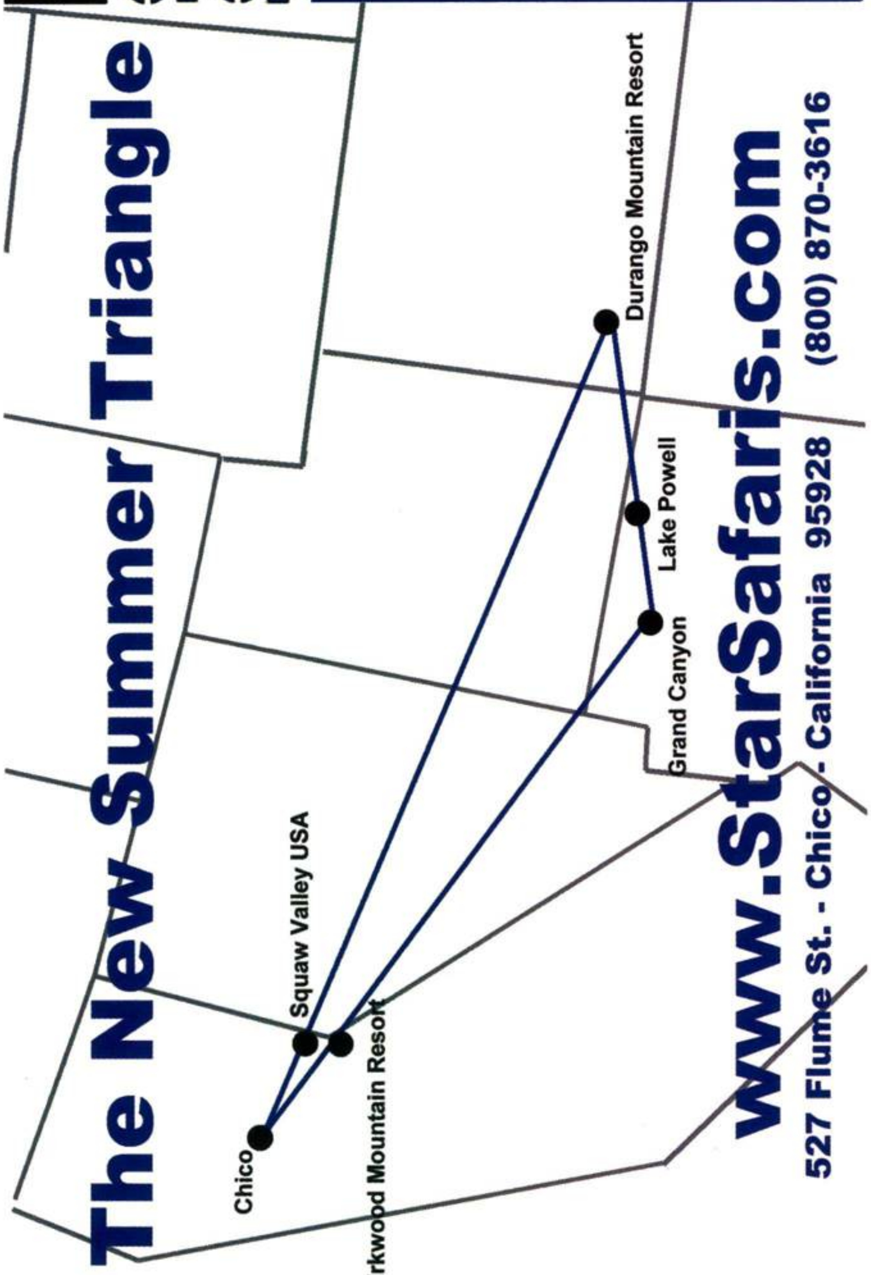

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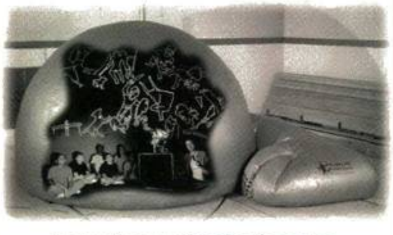

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Interview With An ALIEN

by Steve Mirsky

Astronomy: Terri Field

On an early summer day in 2001, the world was shocked by the announcement that an intelligent alien from another planet had landed on Earth. *Astronomy* magazine quickly arranged to interview the alien at an undisclosed location. Here is an edited transcript of that interview.

ASTRONOMY: Welcome to Earth.

ALIEN: Thank you very much, it's a pleasure to be here.

ASTRONOMY: What is your name?

ALIEN: Klaatu. Just kidding. You can call me Marklar.

ASTRONOMY: Why are you here, Marklar?

ALIEN: To seek out new life and new civilizations. Again, just kidding. See, we learned about you from the TV shows you broadcast all the way to our planet.

ASTRONOMY: Since you brought it up, where is your planet?

ALIEN: Well, I'm not supposed to disclose that, for reasons of planetary security. But I can give you a hint. You know those people who won't eat meat, or even cheese or milk?

ASTRONOMY: Vegetarians?

ALIEN: Vegans, actually.

ASTRONOMY: Yes, what about them?

ALIEN: You know that singer Suzanne Vega?

ASTRONOMY: Yes, we've heard of her.

ALIEN: Okay, look, I'm on a satellite hookup with 45 radio stations in three hours starting the minute we're done, so let's move on. I'll tell you one other thing, though. Our orbital plane is perpendicular to Earth's orbit, so good luck trying to find us until you get a lot more clever interpreting dust disks.

ASTRONOMY: Whatever you say. You look indistinguishable from a human being. Is this a form you've adopted for our benefit, or is this your natural appearance?

ALIEN: No, this is the way we really look. There's a certain amount of biological determinism involved. You want a technological civilization with language, books, complex machines, spaceflight, etc., you wind up with a bilaterally symmetrical, upright biped who doesn't have to spend all day shaving. We've got DNA, the whole works. It's what you call convergent evolution. But there are differences. For example, our eyes evolved correctly, like your cephalopods' did. So we have no blind spot. And we have six fingers on each hand.

ASTRONOMY: Indeed you do.

ALIEN: Yeah, we can really play the piano. On the other hand, I can't flip you off — no middle finger. We obviously didn't miss that til we started receiving your transmissions, but now it seems a shame, as it's apparently a great source of pleasure for many earthlings, particularly cab drivers. But on the whole we're virtually indistinguishable from you physically, that's true. Oh, one other difference. We eat corn on the cob like this. (The alien then motioned as if the corn cob were being held vertically rather than horizontally.)

ASTRONOMY: How did you get here in only the time between your first reception of our tv signals and now?

ALIEN: Again, planetary security issues will limit my answer, but I can tell you this: wormhole. Couldn't have done it without one.

ASTRONOMY: That's fantastic. What kind of incredible things did you see on the trip here?

ALIEN: Well, you've never been in a wormhole, obviously. Not that much to see, I'm afraid. Ever see video of a colonoscopy? Not all that different. But lots of interesting things on either side of the wormhole.

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ASTRONOMY: Such as?

ALIEN: I've seen things you people wouldn't believe. Attack ships on fire off the shores of Orion. I've watched C-beams glitter in the dark off of Tanhauser Gate.

ASTRONOMY: What's a C-beam?

ALIEN: I have no idea. I was quoting Roy Batty in *Blade Runner*. We love that movie. Anyway, like I say, no idea what a C-beam is, and the only thing happening with Orion is that he's gotten too big for his belt lately. Much like Rutger Hauer, aha ha ha ha.

ASTRONOMY: You have a very relaxed demeanor.

ALIEN: We're an advanced civilization. Listen, we started getting *I Love Lucy*, with the chocolate on the conveyer belt and the Vitameatavegamin, and we immediately determined to come meet you. We figured you were our kind of beings. I realized once I arrived here that you're actually pretty somber, most of you.

ASTRONOMY: Well, I guess we're a more serious species than even we may realize.

ALIEN: Yeah, well, for a species whose individuals are aware of its own mortality, you should loosen up a bit.

ASTRONOMY: What other aspects of Earth life are unexpected?

ALIEN: Well, my biggest shock was when I landed and said, "Take me to your leader," and next thing I know I'm meeting George W. Bush.

ASTRONOMY: Well, he is the President.

ALIEN: I was expecting to meet Kofi Annan, actually. We figured he was leader of the whole world. But Bush was nice. We played video games. He's good.

> I realized once I arrived here that you're actually pretty somber, most of you.

ASTRONOMY: We were talking about the incredible things you observed during your journey.

ALIEN: Well, obviously the near end of the wormhole is not right outside of Waukesha, Wisconsin, so I had an opportunity to check out your entire solar system from above the ecliptic. Quite lovely. Although Martin Amis was dead right about Pluto.

ASTRONOMY: I'm sorry, we're not familiar with the reference.

ALIEN: It's in Martin Amis's book, *The Information*, which I happened to pick up at Kofi Annan's home when I eventually did meet with him. Amis writes glowingly of the rest of your solar system and then notes, "One shouldn't mock the afflicted, of course, but Pluto really is an awful little piece of s--t." He also refers to Charon as "another toilet." Correct on both counts. I understand there's a movement to boot Pluto clear out of the solar system. Although to a degree it's just semantics. I mean, if a cat has kittens in the oven, that don't make 'em biscuits, as the saying goes. Pluto is what it is, whatever you call it. And whatever you do wind up calling it, Amis is still right. Don't worry, Clyde Tombaugh can't hear us.

ASTRONOMY: What's the best thing about Earth?

ALIEN: Oh that's easy. This amazing coincidence you all pretty much take for granted, about your sun and your moon having almost identical relative sizes. So you get these truly stupendous eclipses. You know, your sun is 400 times larger, but 400 times farther away from you as is your moon. You know what the odds of that are? I mean, we can get the same effect by getting in a ship and flying to a point in space where one of our moons is the same relative size as our sun. But what a hassle compared to sitting on your back porch and getting a good view of the corona. It's one of the reasons we're planning to set up a permanent tourist office here. Right after we colonize. Just kidding, we come in peace, yada yada yada. Another great thing about Earth is elephants. Ooh, and Trappist Monk Ale. And anything parmigiana.

ASTRONOMY: You were just kidding about the colonization thing, right?

ALIEN: "To Serve Man—it's a cookbook!" Forget that stuff. We don't eat anything with eyes, except potatoes, haaaaa. And we hate red tape, and there's nothing like a colony for generating red tape. What we'd like to do is a little technology transfer, bring you up to speed a bit and establish a trade mission. Much easier, and plenty of quatloos to be made by everyone.

ASTRONOMY: Well, Marklar, thank you very much for the opportunity to meet with you today.

ALIEN: My pleasure. Can I get a copy of the magazine when it comes out?

ASTRONOMY: Of course. How can we get it to you?

ALIEN: You better FedEx it. Regular mail could take forever. ■

Steve Mirsky writes a regular column for Scientific American, *and still, that magazine keeps him employed as a member of its editorial board. He also writes for* Astronomy *as often as we can persuade him to do so.*

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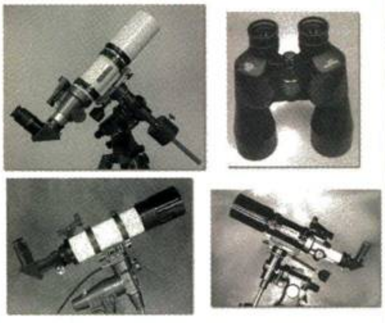

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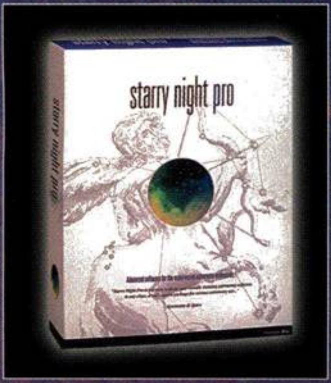

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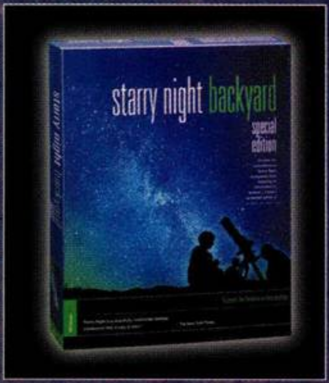

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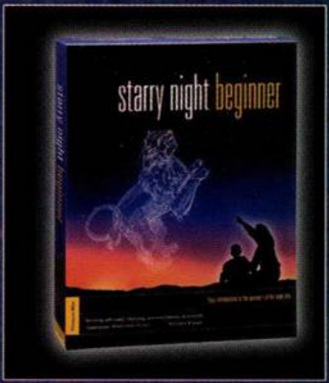

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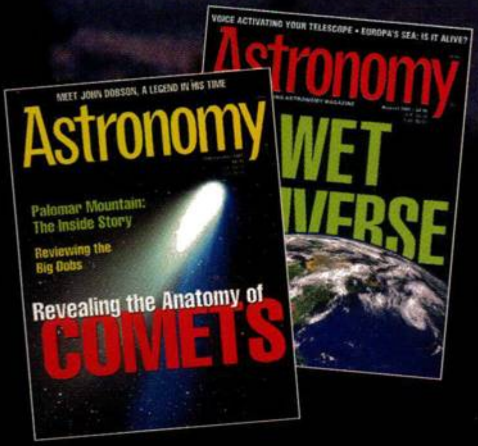
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Exploring the Milky

The greatest star clusters and nebulae provide a personal tour of the hot spots of our home galaxy.

by Tom Polakis

Stand outside on a dark night and look closely up at the Milky Way. You'll see only a portion of our galaxy's disk — Earth blocks seeing more than a little of it at a time. But what if you could take a tour of the entire Milky Way, sampling its highlights along the way? Twenty-four of the greatest objects in the galaxy follow, one chosen for every hour of right ascension around the sky, to provide a tour that walks you right around the whole circle of sky and dips you into both hemispheres.

We begin at zero hours of right ascension in the northerly constellation Cassiopeia, nearly overhead at dusk at the beginning of the year. Here the Milky Way takes on a rather weak, mottled appearance with hints of patchy structure. On the best nights an extremely faint wedge of the Milky Way seems to extend northward all the way to Polaris. Moving eastward, the galaxy turns slowly to the south into Perseus and Auriga. We are now looking opposite our galaxy's center, as the paleness of the misty band will testify. Even so, the starry Perseus OB1 association, between Alpha (α) and Delta (δ) Persei, is a fine sight. In Auriga,

The Pleiades cluster in Taurus. Bill and Sally Fletcher

Way's Best

Above: The Owl Cluster (NGC 457) in Cassiopeia; right: reflection nebula M78 in Orion. Michael Stecker and Lee C. Coombs

the Milky Way is nearly uniform and 20° wide, presenting the typical manifestation of the winter Milky Way.

Our galaxy's band bends abruptly south through Gemini, Orion, and Monoceros, where very subtle parallel dust lanes can be glimpsed in Monoceros under the best conditions. But the uniform appearance persists all the way into Puppis, which is where northern observers begin to lose the Milky Way in spring months. Here, the galaxy's visible width is about 15°. As the Milky Way traverses the southern constellations of Vela and Carina, we are now looking 90° from the center into fields that are clumpy with dark nebulae. In Crux we come across the most pronounced dark nebula in the Milky Way, the Coal Sack — a 5° spot that contrasts dramatically with the surrounding bright star clouds. This is the southernmost extent of the Milky Way. The scene is enhanced by Alpha and Beta (β) Centauri just to the east serving as pointers to the Southern Cross.

The Milky Way begins to return northward in Norma, which is highlighted by a bright star cloud just below the stinger of Scorpius. The Norma star cloud is symmetrically placed around the galaxy's center, with the Scutum star cloud to the north. We are now approaching the galactic center, and the star fields are complex, alternating between those that are dazzling and obscured. Now we move into the hub of activity — the galaxy's center in Sagittarius. This part of the Milky Way is high enough to be seen well at northern latitudes in summer months, but the best vantage point is the Southern Hemisphere, where it's straight up. The Milky Way's central bulge extends to a width of 45° when viewed from dark sites. The highlight is the Sagittarius star cloud, which is so bright as to seem almost featureless. No less than 28 of Messier's 107 objects occupy a 30° radius around the galactic center.

As we emerge from the galaxy's center, the most prominent facet is the Scutum star cloud to the north. This is followed by the best display of the prominent Great Rift, a long dividing lane of obscuring dust that splits the band from Aquila through Cygnus. Passing overhead on autumn evenings, the Cygnus Milky Way's main feature is an oval, uniform field of stars measuring 15° by 5°. Near Deneb, the North America Nebula is faintly visible to unaided vision. Here the galaxy has a similar mottled appearance as it does in Vela and Carina, symmetrically opposite the center. The galaxy's glow fades a bit, and passes next into Lacerta and Cepheus before returning to Cassiopeia.

0h–4h R.A.: Focus on Northern Clusters

The first hour of right ascension is represented by our most northerly object, **NGC 40**, a planetary nebula with a central star of magnitude 10.6 visible in the smallest of instruments. Small scopes show a circular disk about 40" across. The planetary bears magnification well, so use 300x in a 12-inch scope to see the enhancements along the east and west edges. In particular, the western rim appears like a galaxy's spiral arm, terminating near a 14th-magnitude star. The region around the central star is complex and mottled. NGC 40 displays a network of filaments out to a radius of 2' in deep exposures. The best estimate of its distance is 3,000 light-years.

The bright open cluster **NGC 457** is easily found 2° south-southwest of 3rd-magnitude Delta Cassiopeiae. Two "wings"of stars have earned the cluster nicknames such as "Owl" and "Airplane." Lying in the Perseus spiral arm at a distance of 8,000 light-years, it is most impressive to realize that the 5th-magnitude star Phi (ψ) Cassiopeiae is actually a member, some 50,000 times as luminous as the sun. A small telescope is all that's required to see this cluster well, as several dozen stars are brighter than 12th magnitude. The east wing of the cluster is a chain of four bright stars in a nearly perfect line, while to the west lie two pairs of stars arranged in a long rectangle. The "eyes" of the Owl resemble the twin stars Castor and Pollux.

Any casual naked-eye sweep from Cassiopeia into Perseus will turn up the **Double Cluster** (NGC 869 and NGC 884). Small refractors with their wide fields frame these two colorful clusters best. Of the two groupings, NGC 869 is the richer, containing 30 9th- and 10th-magnitude stars across a 10' diameter. About 200 stars reside in this cluster. NGC 884 holds more bright stars, but is markedly less concentrated than its neighbor. Look for a dense group on the southwest edge. Both clusters are about 7,000 light-years away.

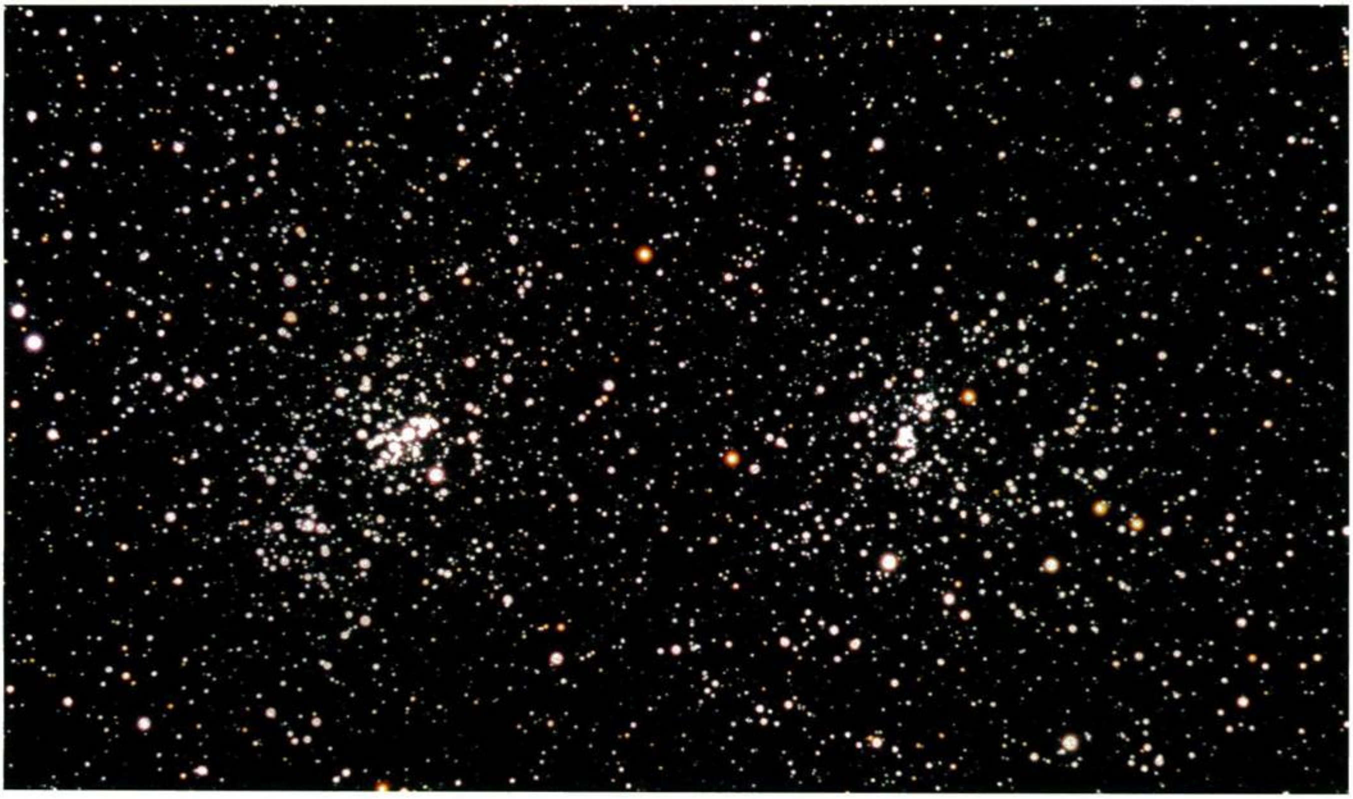
Again beckoning to the naked eye as we pan farther east is M45, the **Pleiades** star cluster. Unaided eyesight immediately picks out six Pleiads forming a dipper shape. Those with excellent vision at good sites can spot over a dozen. The cluster comes into its own through binoculars, showing dozens of stars. In particular, a chain of eight stars run south from the dipper's bowl. The most pleasing view of the Pleiades comes through a small scope that is capable of providing a 3° field of view. As you look, note that cluster members have been found as far as 5° from the center of the Pleiades.

Stepping up to larger scopes, it is worth looking for the reflection nebula that envelops the Pleiades. The Merope Nebula is the brightest part, seen in a 6-inch as a gauzy haze about 10' across radiating south from the bright star. Often it is not aperture but smooth, contrasty optics that do the best job discriminating these faint nebulae from almost blinding stars. Several ambitious observers have succeeded in spotting IC 349, a tiny bright nebula only 30" south of Merope. It is apparently a circumstellar envelope of a hidden star unrelated to the rest of the nebulosity. The remaining nebulosity is explained as reflected light from interstellar dust that happens to be passing through the cluster.

4h–8h R.A.: Strangely-Shaped Nebulae

Moving well to the north into the obscure constellation Camelopardalis, we come upon the planetary nebula **NGC**

Left: Hubble's Variable Nebula in Monoceros; below: The Double Cluster in Perseus. Jack Newton and Michael Stecker



1501. Seen from a distance of 4,000 light-years, the shell of this planetary shows a bumpy structure that is explained by the interaction of the fast wind from the central star with the nebular gas. The 14th-magnitude central star has been the focus of astroseismology studies, as it exhibits very small brightness variations with complex periods on the order of 20 to 90 minutes due to its pulsations.

Find NGC 1501 by following a remarkable chain of 15 stars nearly 3° long visible in binoculars. This pattern is now known as Kemble's Cascade, first noticed by the late deep-sky observer Lucian Kemble. As with NGC 40, high magnification works best for showing NGC 1501. A 10-inch scope shows the central star surrounded by a thick ring 50" across. Inside this ring is a mottled structure that becomes much more apparent with increasing aperture. I find the view at high power with no nebula filter to be the most revealing.

Orion is home to one of the sky's brightest reflection nebulae, **M78**. The object shows two bright concentrations in a 6-inch scope, both surrounding 11th-magnitude stars. The overall shape is a 4' circle with a sharp northern edge, and a very diffuse southern extent. As part of the same complex, NGC 2067 is separated from M78 by a dark lane to the north-northwest. This cloud is 3' across and much fainter than its neighbor. About 15' to the north-northeast is NGC 2071, which is 2' across with a bright center. Backing off to a magnification that yields 1°, a bright gray field devoid of stars indicates the presence of a large molecular cloud.

Indeed, M78 is situated in the Orion B molecular cloud – the nearest region of active OB star formation. This single cloud, only 1,300 light-years away, extends southward from M78 across the Flame Nebula before ending near the Horsehead Nebula. Starlight in this area is typically extinguished by some four magnitudes. In a 1° field around M78 lie 17 shock-excited nebulae in star-forming regions known as Herbig-Haro objects.

Near an asterism that resembles a Christmas tree is the exotic **Hubble's Variable Nebula** (NGC 2261). This is a rare example of a deep-sky object that changes its appearance over periods as short as days. The variability is a result of shadows cast by dust streamers only a couple astronomical units from the illuminating star R Monocerotis. From Earth we see a thin parabolic shell illuminated from below by R Monocerotis, which varies by four magnitudes.

One of the sky's best two-object combinations, the planetary nebula **NGC 2438** floats amid the sea of stars of open cluster M46. In an 8-inch scope, M46 shows 100 similarly bright stars across a circle 25' in diameter, with the planetary lying on the northern edge. It has a subtle ring structure that comes into view at 200x and several superimposed stars, along with the 17th-magnitude central star. A survey of proper motions of the cluster and planetary would indicate that the two are not related, but planetaries are notoriously difficult to gauge, and the distance remains unknown.

8h–12h R.A.: Into the Deep South

Now we move into the realm of the southern Milky Way in Vela. The **Vela Supernova Remnant**, the remains of a star that exploded 12,000 years ago, is the largest such object in the sky, spanning some 5°. Presently we see the collision zone between the star's material and swept-up interstellar gas. A nebula filter in a modest telescope gives an astonishing view. Strands of nebulosity appear in one field after another. Only one feature has a popular designation; NGC 2736 is a plume ½° long that strongly resembles the Veil Nebula in the vicinity of 52 Cygni.

The bright open cluster M46 in Puppis appears to surround the planetary nebula NGC 2438. B. Frank Hinson and Steve Foster

As one of the five best globular clusters in the sky, **NGC 2808** simply grows more and more stunning with each upward step in aperture. In an 8-inch telescope, the cluster shows countless 13th-and 14th-magnitude stars across a ball that is well-concentrated to a sharp center. In a 16-inch scope, the dizzying swarm is at least 10' across and fully resolved. Including the streamers seen at the edge, the overall size expands to 15'. NGC 2808 lies 35,000 light-years away.

We stay in the constellation Carina for one of the southern sky's gems, **Eta (η) Carinae** (NGC 3372). As the brightest emission nebula in the sky, it is spectacular with the entire gamut of instruments. With unaided vision it is obviously the brightest spot in the Milky Way and clearly nebulous. With a scope at 40x, the most prominent detail is a dark, V-shaped rift slicing through the nebula's center. In a 4-inch scope, scalloped detail marks its edge. All of the detail is greatly enhanced through a nebula filter.

At the center of NGC 3372 lies the Keyhole Nebula, a dark, obscuring cloud with that distinct shape. Looking at the center of the nebula at high magnification turns up a unique yellow nebula surrounding η Carinae named the Homunculus, or Little Man. In the middle of the 19th century, η Carinae was the sky's second-brightest star, but it is currently suppressed to 6th magnitude by the surrounding

The Eta Carinae Nebula is the brightest emission nebula in the sky and a treat in telescopes. Steven Quirk

nebula. The star's luminosity proves most impressive at more than 5 million suns. Placed at the distance of Alpha Centauri, it would be brighter than the full moon.

Only 3° east of η Carinae is the open cluster **NGC 3532.** Here we see more than 100 stars brighter than 12th magnitude from a distance of 1,500 light-years. The cluster is apparent to unaided vision as an oval concentration of the Milky Way. A 7x50mm finderscope resolves 50 stars from the intense background. In a 4-inch, a 1° field is packed with stars from 7th through 10th magnitudes. A dark lane with no stars runs along the cluster's northern edge. A large number of fainter members comes into view with larger telescopes, but the wider view seems to be the most appealing.

12h–16h R.A.: Southern Stars and Clusters

Now halfway through our tour, we are brought to the small constellation Musca and **NGC 4372**, a globular cluster whose concentration is among the lowest known. At a distance of only 15,000 light-years, its stars appear bright and well-resolved in small telescopes. In an 8-inch scope at 150x, NGC 4372 has the appearance of an open cluster 7' across, with almost no central brightening or background glow. Stars as bright as 12th magnitude make this cluster easy to fully resolve, while a 6th-magnitude star lies only 5' to the northwest.

We now move from a humble globular cluster to the sky's greatest, **Omega (ω) Centauri** (NGC 5139). Weighing in at over 3 million solar masses, it is the most massive globular cluster known. It is also the most luminous, with an intrinsic brightness of nearly a million suns. Factoring in our

GREAT OBSERVING TARGETS OF THE MILKY WAY GALAXY

Object	R.A. (2000.0) Dec.	Mag.	Size/Sep./Per.	Type	Notes
NGC 40	0h13.0m 72°32'	12.4	37"	PN	
NGC 457	1h19.1m 58°20'	6.4	13'	OC	Owl Cluster
NGC 869	2h19.0m 57°09'	5.3	29'	OC	Double Cluster
M 45	3h47.0m 24°07'	1.2	110'	OC	Pleiades
NGC 1501	4h07.0m 60°55'	11.5	52"	PN	
M 78	5h46.7m 0°03'	—	8' by 6'	BN	
NGC 2261	6h39.2m 8°44'	—	3.5' by 1.5'	BN	Hubble's Variable Nebula
NGC 2438	7h41.8m –14°44'	11.0	66"	PN	With M46
Vela SNR	8h30.0m –45°00'	--	1200' by 720'	BN	Supernova Remnant
NGC 2808	9h12.0m –64°52'	6.1	13.8'	GC	
Eta Carinae	10h43.8m –59°52'	—	—	BN	Keyhole Nebula
NGC 3532	11h06.4m –58°40'	3.0	55'	OC	
NGC 4372	12h25.8m –72°39'	7.3	18.6'	GC	
NGC 5139	13h26.8m –47°29'	3.5	36'	GC	Omega Centauri
Alpha Cen	14h39.6m –60°50'	0.0/1.2	14"	Dbl	
NGC 5822	15h05.2m –54°21'	6.5	39'	OC	
NGC 6067	16h13.2m –54°13'	5.6	12'	OC	
NGC 6302	17h13.7m –37°06'	9.6	50"	PN	Bug Nebula
B 86	18h03.0m –27°53'	—	5'	DN	
Beta Cyg	19h30.7m 27°58'	3.1/5.1	34"	Dbl	Albireo
NGC 6992	20h56.4m 31°43'	—	60'	BN	Veil Nebula
NGC 7008	21h00.6m 54°33'	10.7	83"	PN	
NGC 7380	22h47.0m 58°06'	7.2	20'	OC	
NGC 7789	23h57.0m 56°44'	6.7	15'	OC	

favorable vantage point only 20,000 light-years away, Omega Centauri is a huge object, fully a half degree across.

Easily visible to unaided vision as a fuzzy star, Omega Centauri begins to resolve into stars in large binoculars. A 6-inch fully resolves the cluster, showing countless members sparkling across a 20' diameter. This globular is more oval than any other one in our galaxy.

Alpha Centauri is celebrated not only as a member of the closest star system, but also as a magnificent binary star. As such it has been studied for 250 years, and its orbit is well-known. The magnitude-1.3 secondary star completes a circuit about the zero-magnitude primary every 80 years. The brighter component is similar to the sun in both color and luminosity. While the two stars are currently separated by a comfortable 13", the separation will be halved in only eight years. The brighter component of the binary system appears white, and its slightly fainter companion takes on a yellowish hue. A third, probable member of the star system is Proxima Centauri, an 11th-magnitude dwarf over 2° away from the bright pair.

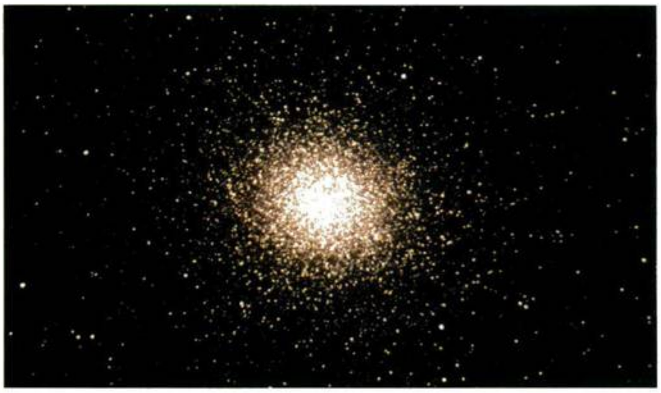
Located 2½° south-southwest of Zeta (ζ) Lupi is the rich open cluster **NGC 5822**. Placed 3,000 light-years away, some of its 150 stars are as bright as 10th magnitude. Telescopically, the cluster presents nearly 100 stars nicely scattered across a 40' field. The southwest half of the cluster is more densely packed with stars than the northeast.

16h–20h R.A.: Challenging Stars and Nebulae

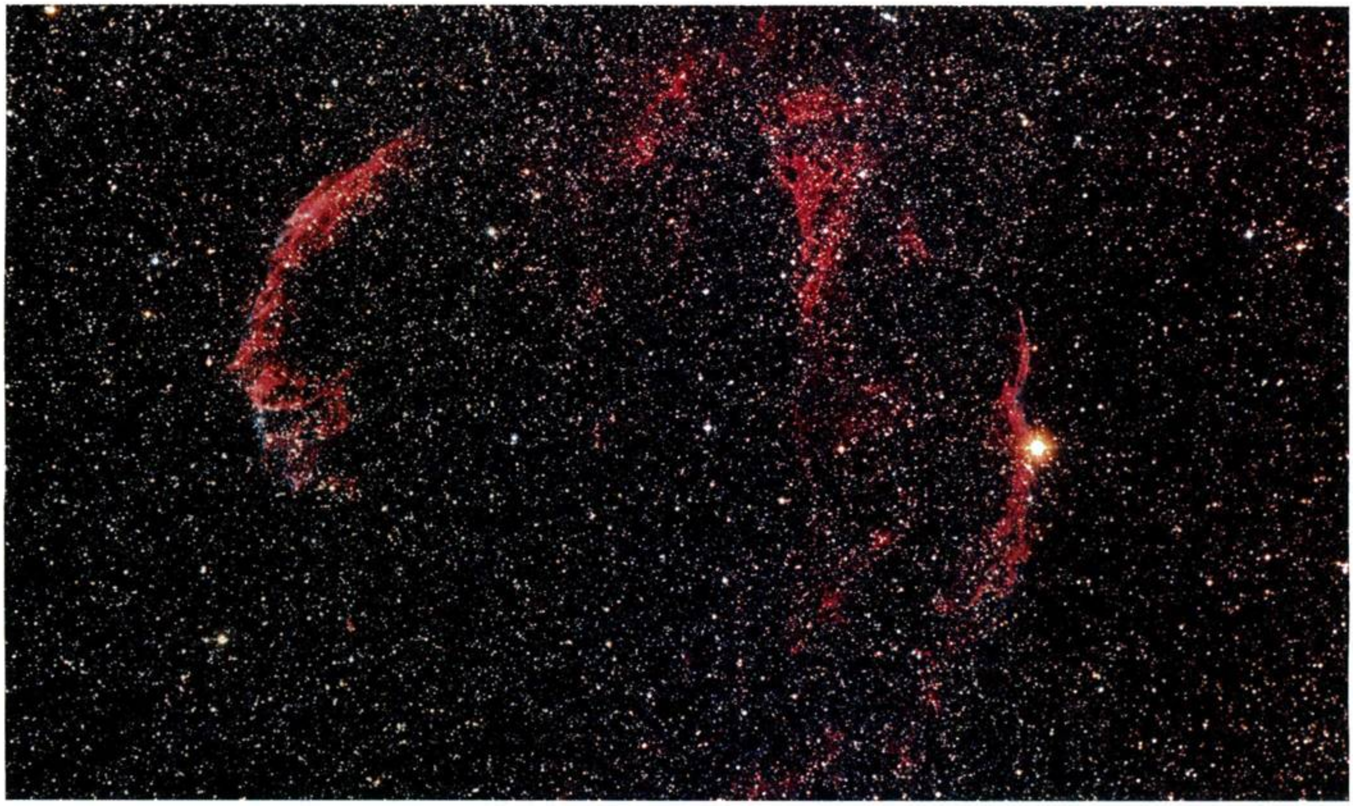
Situated in the middle of the Norma star cloud, **NGC 6067** is one of the sky's greatest open clusters. This object has a wide assortment of star colors among its 100 bright member stars. At a distance of 7,500 light-years, it appears to be similarly placed as the Norma OB1 stellar association. NGC 6067 contains 60 stars brighter than 13th-magnitude, making it an excellent object for small scopes. In a 10-inch, the full extent of the cluster is 15' across, where about 75 stars are visible. At the center is a prominent orange star with a similarly bright companion 20" to the east. The overall appearance of the cluster is similar to M35, but the central region is more crowded.

In the middle of the stinger of Scorpius is a strange planetary nebula that looks like a tiny edge-on galaxy 80" long and 20" wide. This is NGC 6302, the **Bug Nebula**. To the west of the center is a bright lobe that tapers to the end. The eastern half has a blunt end and what seems like a faint arm. Located 5,000 light-years away, NGC 6302 is known to be one of the most massive planetaries, containing an unseen central star whose light is obscured by surrounding dust.

Once thought of as "holes in the heavens," dark nebulae have quite a history. In a classic 1917 paper, Edward E. Barnard argued in favor of the notion that dark nebulae are obscuring clouds. He described one such object, now known as **Barnard 86**, as "a drop of ink in the luminous sky."



Below: Open cluster NGC 3532 in Carina; right: Globular star cluster Omega Centauri. Luke Dodd and Jason Ware



Above: The Veil Nebula in Cygnus; left: open cluster NGC 6520 and dark nebula B86. Bill and Sally Fletcher and Jack Marling

The southern star in Cygnus, the Swan, is Beta Cygni, more commonly known as **Albireo**. A favorite at star parties, this colorful double star is likely a true binary, even though no orbital motion has been found in over a century of observation. A small telescope at 20x splits the two components: an orange, 3rd-magnitude primary offset by a bluish secondary of 5th magnitude 34" away.

20h–0h R.A.: The Riches of the North

The **Veil Nebula** (NGC 6960 and NGC 6992–5) has become another star party regular due to the availability of nebula filters. It is a remnant of a supernova that occurred 30,000 years ago. Strands of nebulosity cover an area of sky nearly 3° by 4°. At 20x in a small telescope, both arcs of the nebula are visible as segments of the giant shell. A larger scope with an Oxygen III filter hints at filamentary structure worthy of the name. Still larger aperture shows the two individual sections as very distinct objects. Near 4th-magnitude 52 Cygni is NGC 6960. The degree-long strip has a sharp northern point and broadens to the south, where it is divided by a lane. Two degrees to the east is NGC 6992, which is brighter, and more complex. Be sure to look between the two main arcs for numerous small filaments that are visible only with a nebula filter in place.

Remaining in Cygnus, the planetary nebula **NGC 7008** is visible in small scopes, but really requires large aperture to be appreciated. At 300x in a 16-inch scope, it presents a large ring that opens to the south with embedded clumpy structure. Under dark skies, a dim knot 22" northwest of the central star may be visible. This is K4–44, which is a separate planetary nebula in the background of NGC 7008.

Some 2° east of the archetype variable star Delta Cephei lies the open cluster and associated nebula **NGC 7380**. Located 10,000 light-years away, the modest cluster contains about 40 stars as bright as 9th magnitude in an area 8' across. The brightest members are arranged in a V-shape. Surrounding fields are rich with stars, making the edge of the cluster difficult to define. The nebulosity that photographs so well is difficult to spot even in large scopes until a nebula filter is employed. Curdled nebulosity covering the entire cluster extends faintly to the north.

Our final hour of right ascension is represented by **NGC 7789**, an open cluster that responds dramatically to aperture. In an 8-inch telescope, it presents over a hundred members, but larger aperture increases this number greatly. An aspect that doesn't show photographically is an illusion of crossing dark lanes brought on by so many similarly bright stars. 15,000 members are known to inhabit this old cluster, which we see across a distance of 9,000 light-years. ■

Tom Polakis, a frequent contributor to Astronomy, *is an aerospace engineer living in Tempe, Arizona, who is also a deep-sky observer.*

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Astronomy Bookshelf 2002

Choose from a variety of astronomical categories as you update your bookcase with these recent publications.

by Carol Ryback

It's time to take a look at your bookcase and consider whether the astronomy shelves are half empty or half full. Half empty? You'll find many positives surrounding that extra room. Use this handy ***Explore the Universe 2002*** guide and dedicate one shelf to each of the different astronomy-related categories. You'll not only end up with a rounded selection that complements your knowledge, but you'll also ease the decision-making process for what to buy next. Choose from among these fresh titles to update your existing astronomical collection.

Start with your observing shelf. Beginners will especially like the ***Cambridge Guide to Stargazing Without Your Telescope***, by Robin Scagell. The title says it all, but this book serves as a great introduction for novices and as a refresher for anyone whose observing skills need some renewing. As you enjoy the night sky with your bare eyes, you'll soon discover that Peter T. Wlasuk's ***Observing the Moon*** is the perfect companion on those nights when the stars are all but obscured by our nearest celestial neighbor.

No dedicated observer lasts long without binoculars or a telescope, so you might consider adding any of the following sky guides to your collection: ***Celestial Sites, Celestial Splendors***, by Hervé Burillier, ***The Planet Observer's Handbook, 2nd Edition***, by Fred W. Price, and the ***Cambridge Guide to Stargazing With Your Telescope***, by Robin Scagell. And don't forget ***The Southern Sky Guide, 2nd Edition***, by David Ellyard and Wil Tirion, especially if you live in or plan on visiting the southern latitudes.

On those cloudy nights when observing isn't an option, travel vicariously into space with ***Sputnik: The Shock of the Century***, by Paul Dickson, and then join Chris Kraft in ***Flight: My Life in Mission Control***, or Hamish Lindsay from a slightly different perspective in ***Tracking Apollo to the Moon***. More armchair travel and exploration awaits if you include ***Taking Science to the Moon***, by Donald A. Beattie. Then, completely round out your virtual trip with ***Spacefaring: The Human Dimension***, by Albert A. Harrison, for a look at spacecraft ergonomics.

Now that you've filled your manned space exploration shelf, trek out further into the cosmos on your own search for ***Life Everywhere: The Maverick Science of Astrobiology***, by David Darling. Along the way, you may encounter a burning need to read ***The Magic Furnace: The Search for the Origins of Atoms***, by Marcus Chown, or stop to ponder ***Destiny or Chance: Our Solar System and its Place in the Cosmos***, by Stuart Ross Taylor.

It's a good bet you'll also start contemplating the beginning of life itself with the help of Lawrence M. Krauss and his ***Atom: An Odyssey From the Big Bang to Life on Earth ... and Beyond***. And if that's not enough, experience the thrill of extragalactic exploration in ***Our Universe***, a series of essays by leading astrophysicists, edited by S. Alan Stern.

With your mind — and another bookshelf — wide open, keep time to ***Einstein's Unfinished Symphony***, as Marcia Bartusiak describes the search for gravitional waves and their relation to the space-time continuum. Companion books in this dimension include ***Timeless Reality***, by Victor J. Stenger, and ***Time Travel in Einstein's Universe***, by J. Richard Gott. Explore theories on how we can determine the origin of the universe in ***Supersymmetry***, by Gordon Kane. Insert practicality into your musings and discover how we're making progress in understanding these questions with ***Revealing the Universe: The Making of the Chandra X-Ray Observatory***, by Wallace Tucker and Karen Tucker.

Counteract that brain-exercise bookshelf with tomes that contain tangible resources for your astronomical pleasure. An overall reference such as the ***Facts on File Dictionary of Astronomy, 4th Edition***, by Valerie Illingworth and John O. E. Clark, helps clarify arcane trivia or unfamiliar terms you encounter. Such basic knowledge comes in handy when you turn your focus to common astronomical subjects like the sun, Mars, or asteroids.

Leon Golub and Jay M. Pasachoff offer a fascinating look at the center of our solar system with ***Nearest Star: The Surprising Science of Our Sun***. Likewise, William Sheehan and Stephen James O'Meara do the same in ***Mars: The Lure of the Red Planet***. Finally, Curtis Peebles takes you along for a hard look at ***Asteroids: A History***. And, if you're curious to know what's going on across the spectrum of astronomy and astronomical research and where it's all headed, add the National Academy Press's ***Astronomy and Astrophysics in the New Millennium*** to your shelf.

Next, try adding some personality. ***Percival Lowell: The Culture and Science of a Boston Brahmin***, by David Strauss, describes the life and times of a controversial but astronomically important man best remembered as someone who looked through his own telescope at life here — and in the canals on Mars.

Two other books — ***The Neptune File: A Story of Astronomical Rivalry and the Pioneers of Planet Hunting***, by Tom Standage, and ***Parallax: The Race to Measure the Cosmos***, by Alan W. Hirshfeld, aren't biographies, but they tell compelling stories that are key to the history of astronomical research.

Perhaps the most avant-garde biography available for your shelf is ***$E=mc^2$*** by David Bodanis. Here, you're treated to a look at the equation that transformed the world as if it's an entity in and of itself.

If your astronomy bookshelves are now overflowing, maybe it's time to move out onto the coffee table instead. Choose from these six new beauties to mix and match as you see fit. Take a dreamy trip through space with either ***Celestial Treasury: From the Music of the Spheres to the Conquest of Space***, by Marc Lachiez-Rey and Jean-Pierre Luminet, or ***Life Beyond Earth***, by Timothy Ferris. Both books are stocked with plenty of visual and philosophical fodder good for hours of celestial daydreaming.

Chase other elusive objects along with Serge Brunier and Jean-Pierre Luminet in ***Glorious Eclipses: Their Past, Present, and Future***. Filled with anecdotes, illustrations, and photos, this book highlights yet another phenomemon-driven astronomical passion.

For a change of pace, ***The Universe Unveiled***, by Bruce Stephenson, Marvin Bolt, and Anna Felicity Friedman, showcases a treaure-trove of objects that added an elegant flare to celestial research in centuries past.

Give the godfather of space art a place of honor on that coffee table when you make room for ***The Art of Chesley Bonestell***, by Ron Miller and Frederick C. Durant III. Then, celebrate the touchy-feely side of space (yes, there is one!) with ***The Infinite Journey***, by William E. Burrows. It's sure to make you feel privy to the heyday of the space race.

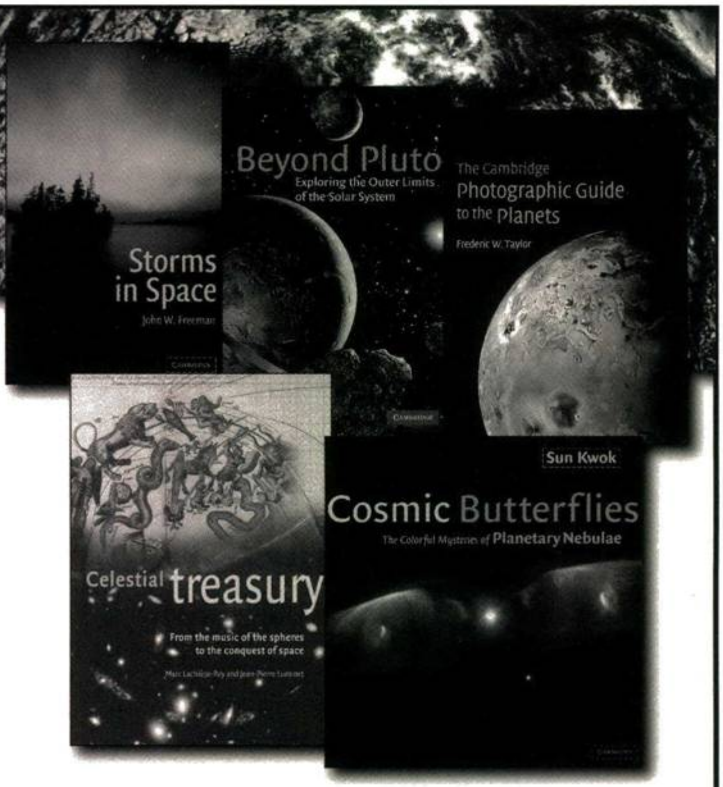
Finally, every bookshelf has room somewhere to shove in a few more. These eclectic titles help create great topics of conversation for your next cocktail party. ***Splitting the Second: The Story of Atomic Time***, by Tony Jones, details the revolution in timekeeping. (Where would space exploration and professional sports be without accurate timing?)

Use the paperback version of ***The Sun in the Church: Cathedrals as Solar Observatories***, by J. L. Heilbron, as a segue from a religious discussion to a seminal one. Then relax and sip your latte while floating the foamy idea of a simple concept for describing the universe with ***Universal Foam: From Cappuccino to the Cosmos***, by Sidney Perkowitz. And just when you think you're out of stimulating topics, thank author K. C. Cole for ***The Hole in the Universe*** and her explanation of nothing at all.

So, over the next few months, take some time to fill in the gaps on your astronomy bookshelves. Try adding one title from each category to update your collection. That way, you'll stay on top of what's new, beautiful, and intriguing in the world of astronomy. **A**

Carol Ryback is an associate editor and books editor for Astronomy *magazine.*

Begin your odyssey through the stars!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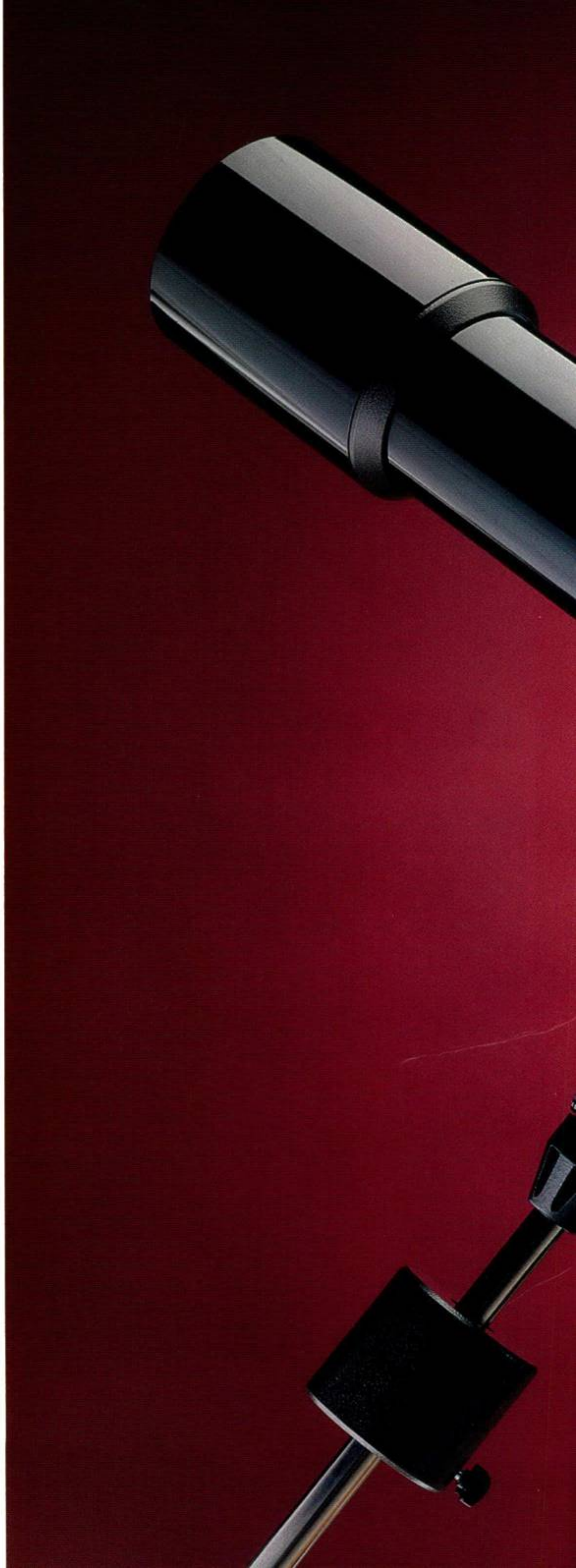
The complete buyer's guide to choosing the first-time scope that's right for you.

by Phil Harrington

Maybe you've had a passing interest in the night sky for years. Or perhaps you pick up an issue of *Astronomy* every now and then, just to keep up with goings-on in the rest of the universe. Whatever the reason, a recent article you read, the amazing photo on the cover, or an assignment that your child brought home, your interest is piqued. You've decided that exploring the universe is no longer a spectator sport. You want to be a full-contact participant. Welcome aboard. You're about to embark upon a hobby adventure capable of yielding a lifetime of nightly satisfaction.

Still, deciding where to begin your foray into amateur astronomy can be a daunting task. A quick glance through the ads in this issue will reveal that there are hundreds of telescopes and related equipment to choose from. That's why we've compiled a list of 50 top beginner telescopes to help you find the telescope that best suits your needs.

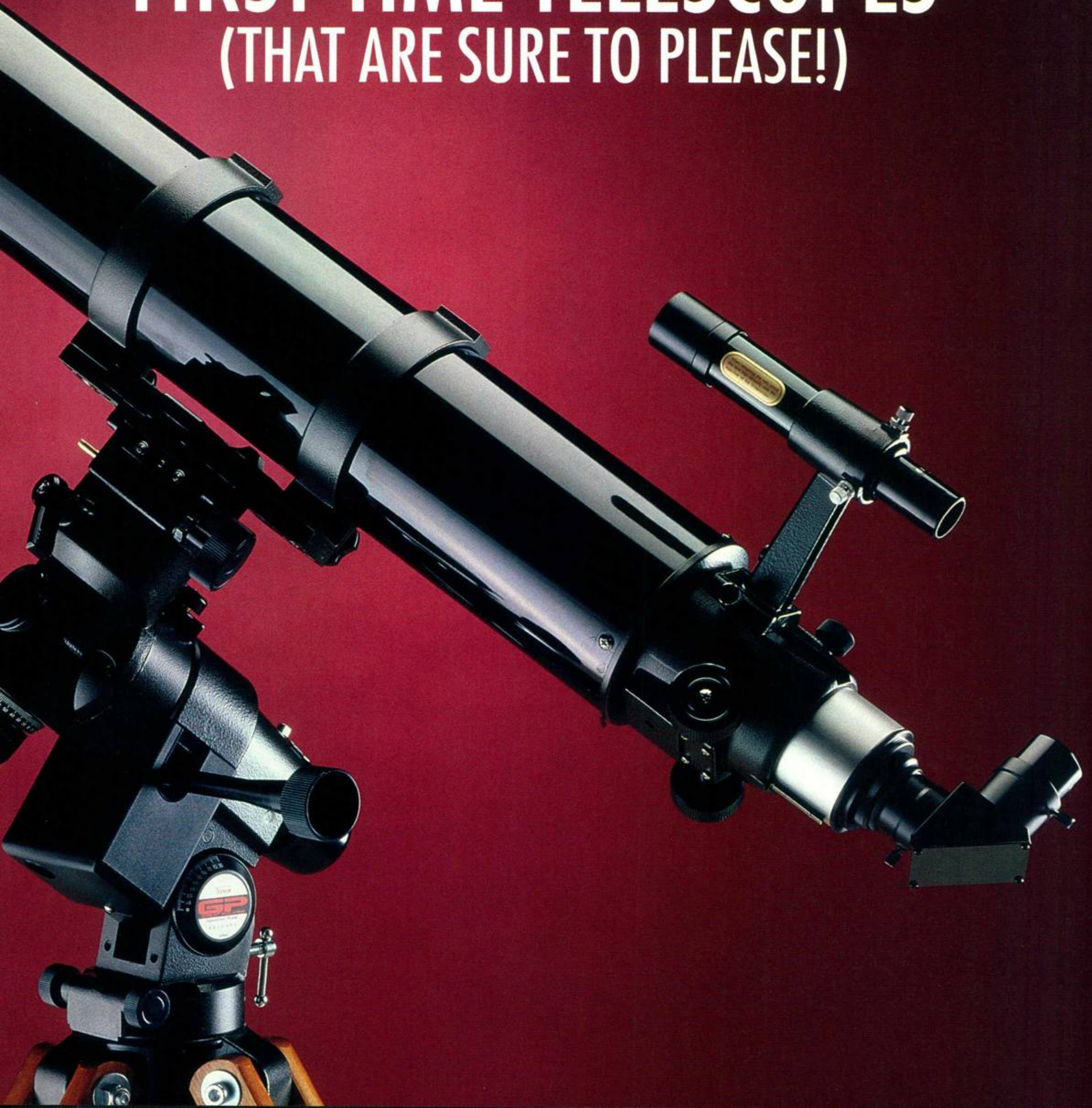


Different strokes: Refractors will bring planets and bright sky objects to life, but won't deliver deep galaxies and nebulae like reflectors can. All photos: *Astronomy*: William Zuback/Jim Forbes

FIFTY

FIRST-TIME TELESCOPES

(THAT ARE SURE TO PLEASE!)



Basic Training

There are three broad categories of telescopes based on their optical design — the refractor, the reflector, and the catadioptric (see "Telescope Types," page 90). But, regardless of their design, all telescopes share many common characteristics and terminology. For instance, we always refer to a telescope's size not by the length of its tube, but instead by its aperture — the diameter of the instrument's main optic lens or mirror (called the objective). The length of a telescope is primarily determined by its focal length, the distance from the objective lens or primary mirror to the focal point, where the light rays come to a focus.

As with aperture, focal length is commonly expressed in inches, centimeters, or millimeters. Telescopes are also characterized by their focal ratio or f/number — simply a number you get by dividing the focal length of the objective by the aperture (see "F/Number," page 93). A 4-inch aperture telescope with a focal length of 40 inches has a focal ratio, or f/number, of f/10, while a 6-inch aperture telescope with a focal length of 48 inches has a focal ratio of f/8.

Optical quality should always be a top priority when selecting a telescope. And be aware that, when it comes to optics, all telescopes are definitely not created equally. Some are outfitted with flawless optics, while others use lenses and mirrors that are barely able to achieve focus. For a mirror or lens to perform properly, its curve(s) must be extremely well-machined.

Manufacturers often say that their telescope optics are diffraction limited. This means that the optics are so good that performance is limited only by the wave properties of light itself, and not by any flaws in the optics. This is an important statement to look for, but you should also double-check their return policy, just in case. All of the telescopes listed here are considered to have quality optics that will produce acceptable images.

CELESTRON
STAR HOPPER

Portability meets deep-sky power with a reflector on a Dobsonian mount.

Decide What's Best for You

Above all else, your wants and desires should be given a high priority when selecting a telescope. Just like buying anything, be it a car, a home, or your next meal, we all have our own unique needs. So, too, it is with telescopes. A telescope that is right for me may not be the best one for you.

First, consider what you want to do with the telescope. What type of observing interests you? Some telescopes are better at viewing, say, the planets than others. If you would like to wade into the world of astrophotography, then you may need a different telescope than if you simply want to poke around. Consider a few options.

Realize that each of the three major telescope types has its own strengths and weaknesses. For instance, if you are most interested in viewing the moon and planets, you should be more concerned with image sharpness than with image brightness. After all, the moon and naked-eye planets are among the brightest objects in the night sky, so a telescope needn't make them brighter. In this case, an achromatic refractor might be your best choice (see "Telescope Types," page 90). Well-made refractors are famous for extremely sharp images and high image contrast, two critical ingredients in a quality planet-watching telescope.

When choosing an achromatic refractor for planet watching, stick with one that has a focal ratio no less than f/8 or so (see "F/Number," page 93). Small refractors with faster focal ratios don't tend to magnify a planet's image sufficiently, unless paired with a very short focal length eyepiece. Except for some very expensive, exotic designs by companies such as Tele Vue, Meade, and Vixen, short focal length eyepieces are very difficult to focus clearly. Refractors with faster focal ratios also suffer from chromatic aberration more than those with higher f/numbers. Chromatic aberration can cloud subtle planetary details (see "Telescope Types," page 90).

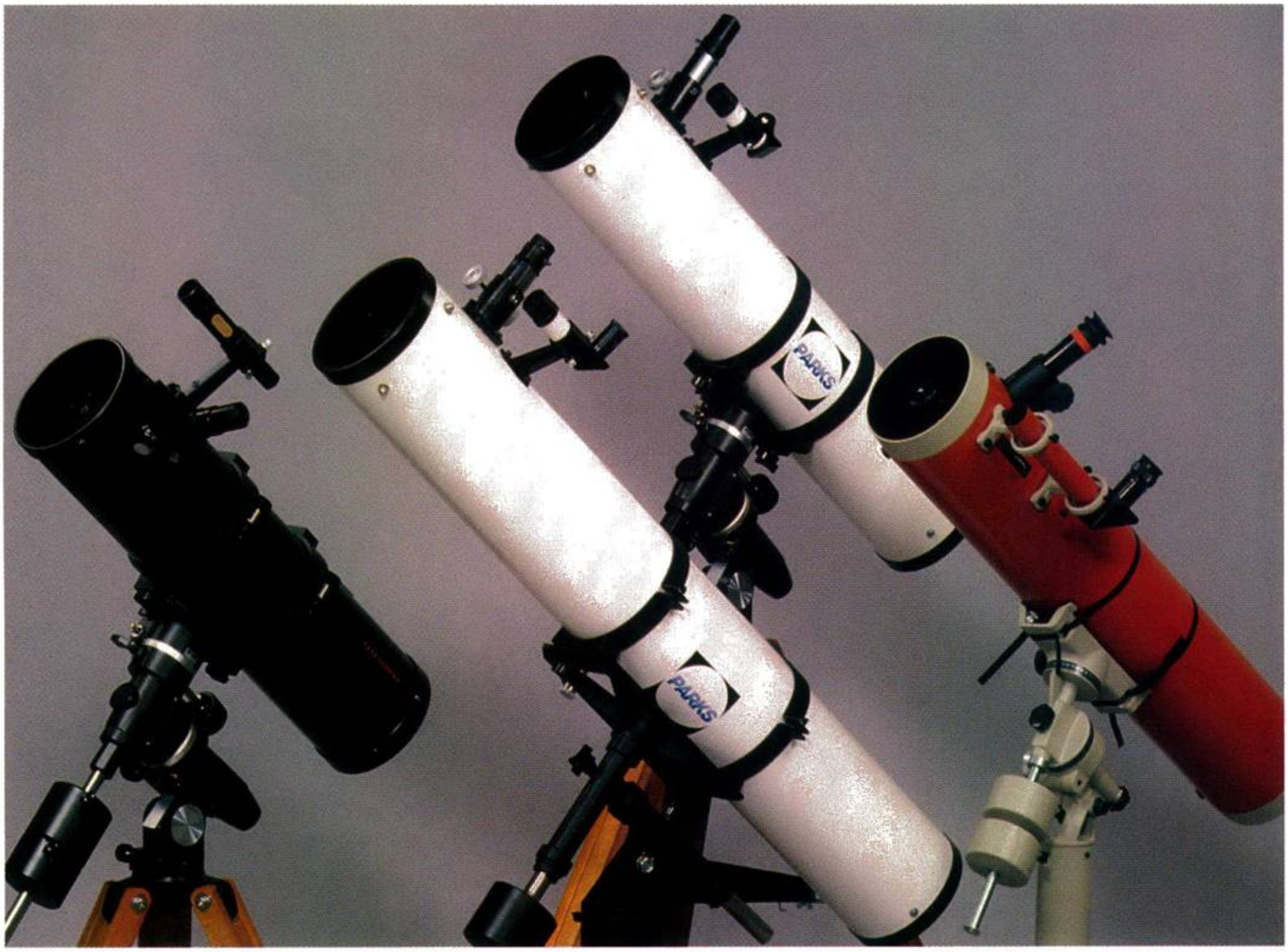
If you prefer to view distant star clusters, nebulae, and galaxies, most beginner-level refractors will prove too small to show much beyond the brightest examples of each. In this case, you are most interested in light-gathering ability, making a reflector your best bet. Inch for inch, reflectors, which are less expensive to make, get you more aperture for your money than any other kind of telescope. But at the same time, don't buy such a large telescope that it proves too difficult to move. Most beginners will probably do best with a 6-inch reflector. If the telescope is for a young child, then a lighter weight 3- or 4-inch reflector would be a wiser choice, while some people may prefer a larger, though heavier 8-inch reflector. Again, the choice will boil down to personal preference and considerations.

What if you live in a high-rise apartment or condominium? If that's the case, then either of these telescopes might be too cumbersome to carry and set up. And you may want to consider looking at a small, "short-focus" refractor or reflector. Short-tubed telescopes are quite popular among urban astronomers because they can be carried outside with one hand, while toting books and charts in the other. There is, however, one caveat associated with this type of scope. Some short-tubed reflectors boast an internal lens that stretches their focal ratios to longer proportions. While most work fine, these auxiliary lenses tend to produce image distortions more readily than those telescopes without them.

Stargazers short on storage space might also consider a catadioptric telescope (see "Telescope Types," page 90). Unfortunately, none of these instruments lie below our self-imposed price ceiling of $500 for this article, and as such, are not included in the accompanying table. An 8-inch Schmidt-Cassegrain, the most popular catadioptric, costs between $900 and $2,000, depending on the quality of the mounting and level of accessories.

Building on a Strong Foundation

Running neck-and-neck in terms of importance when selecting a telescope is the quality of its mount. A good mount must be strong enough to support the telescope's weight while minimizing any vibrations. It must also move smoothly as the telescope slews from object to object, while allowing easy access to any part of the sky.



Telescope mounts come in two flavors: altitude-azimuth (alt-az) and equatorial. Alt-az mounts move both in azimuth (horizontally, left to right) and in altitude (vertically, up and down). Better alt-az mounts are outfitted with "slow-motion controls," one for each axis. By twisting one or both of the slow-motion control knobs, the observer can finely adjust the telescope's aim.

In the past 25 years, a variation of the alt-az mount called the Dobsonian (Dob) mount has become extremely popular for supporting 6-inch and larger Newtonian reflectors. The telescope tube moves up and down on a pair of circular altitude bearings that ride in a rocker box, which sits on the ground and pivots left and right.

Dob mounts are often made from either wood or wood byproducts, such as laminated chipboard. While many may think that a wooden telescope mount sounds very primitive, in reality, wood dampens vibrations far better than metal. So, despite their simplistic appearance, Dob mounts are wonderfully stable.

Both traditional alt-az mounts as well as Dob mounts share some drawbacks. Unless you are observing at the poles, celestial objects will appear to trace long arcs across the sky. With an alt-az mount, the telescope must be nudged both horizontally and vertically in a step-like fashion to keep up with the sky, which is less convenient than the fluid motion of an equatorial mount.

If you are thinking of trying your luck with astrophotography, then it's almost compulsory that you get an equatorial mount. When tilted at an angle to match the observer's latitude, an equatorial mount will track the sky with one smooth motion rather than in choppy steps. Perhaps their greatest benefit is being able to attach a motor drive so that the telescope will follow the sky automatically.

On the down side of equatorial mounts, however, is that they are almost always larger, heavier, more expensive, and more cumbersome than alt-az mounts. And their diagonal motions (relative to the horizon) can take some getting used to.

Compact Newtonian reflectors have a rich history, dating back to their namesake.

There are several different equatorial mount designs, but the two most popular among amateur astronomers are the German equatorial mount and the Fork mount. The German equatorial mount is shaped like a tilted letter "T". The telescope is mounted to one end of the cross bar, while a weight for counterbalance is secured to the other. If properly designed, German equatorial mounts are very sturdy, but at the same time, can be very heavy. A German equatorial mount designed to hold a 6-inch reflector might weigh between 30 and 100 pounds, while a Dobsonian mount would weigh 15 pounds or less.

Fork equatorial mounts, usually supplied with catadioptric instruments, support their telescopes on bearings set between two short "prongs." The prongs usually extend from a turnable circular base, which is usually tilted to match the observer's latitude. The biggest plus to the fork mount is its lightweight, compact design.

Finding Your Way: Finderscopes and Eyepieces

As you can see, there are many important things to look for when purchasing that first telescope. Eyepieces and finderscopes are especially critical. A finderscope is a small, low-power refracting telescope, mounted on the telescope tube to help the observer aim the instrument like a gun sight. Finderscopes are specified in the same manner as binoculars. A 6x30 finder, for example, has an aperture of 30mm and yields 6 power. Most experienced observers agree that this is the smallest useful size for a finderscope. Smaller finders, such as 5x24 finders that come on many department-store telescopes, will show fewer stars, making it more difficult for the observer to find his or her way.

A popular alternative to traditional finderscopes is a so-called one-power aiming device. Several are marketed today, though the original, the Telrad, remains the most popular. Aiming devices let the observer align the telescope by looking through a clear window superimposed with a red bull's-eye or dot. Simply align the bull's-eye with your target and you're there.

Eyepieces are an especially important consideration for your first telescope. They are rated by focal lengths (usually in millimeters), not magnification, since that will also depend on the telescope. When it comes to understanding what you want, it's important to remember the following: Magnification is determined simply by the ratio of focal lengths — the telescope's divided by the eyepiece's. A 25mm eyepiece, for instance, will produce a magnification of 48x in a 6-inch telescope with a 48-inch focal length, but 80x in an 8-inch instrument with an 80-inch focal length.

With a few added extras, you can turn your telescope into a telephoto lens.

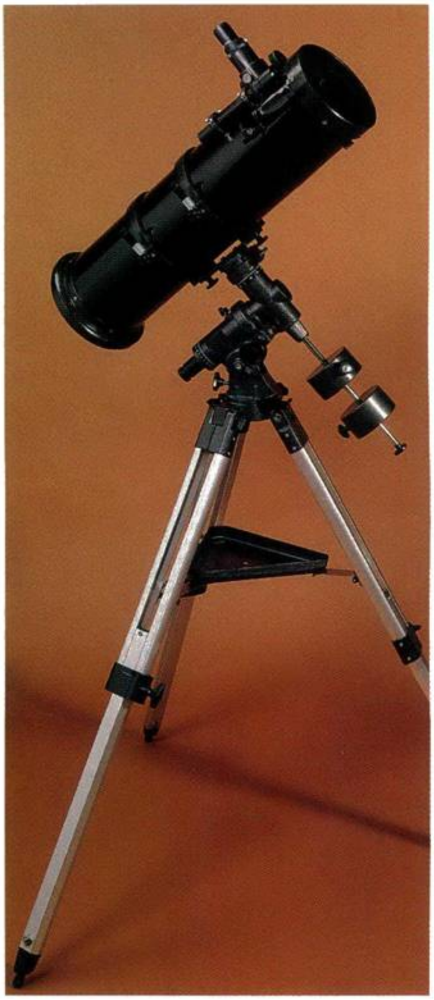
In general, you'll want two or three eyepieces for viewing — one for low power, another for moderate magnification, and a third for high-powered views. Select the appropriate focal lengths based on the aperture of your telescope, remembering the rules of over-magnification cited earlier. A good mix might be a 22mm to 30mm eyepiece for low power, 12mm to 17mm for moderate power, and 7mm to 10mm for high power.

While an eyepiece must be selected based on telescope aperture, the eyepiece barrel must be the proper size to fit into the telescope's focusing mount. All of the telescopes listed here use 1¼" diameter eyepieces (a standard that's existed for years), but many department-store telescopes only accept subdiameter, 0.965" eyepieces. Sadly, these are frequently very poor in quality and greatly reduce telescope performance.

Shop Around, Make Some Friends

When shopping for a telescope, be sure to shop at the right stores. Most toy stores and department stores don't sell high-quality telescopes. Many camera stores sell a few top-notch telescopes intermingled with an overabundance of poor imitations, making it difficult to tell one from another. Ask the salesperson's advice, but remember they are trying to sell you something, so take their counsel with caution. All of the telescopes listed in the accompanying table are far better than any sold in mass-market outlets. You will find many of them advertised throughout the pages of *Astronomy*. Again, look each over carefully to see if it meets your needs and desires.

Some telescopes are sold through networks of dealers, while others are only sold directly from the company to the consumer. If you plan on purchasing an instrument from a dealer, make your decision on more than just price alone. Ideally, it is best to purchase from a local outlet, but if one isn't available in your area, then mail order may be your only alternative. In that case, make certain to ask the manufacturer about hidden costs, such as exorbitant shipping and handling charges.



Telescope, mount, eyepieces, and finderscope complete the beginner package.

Perhaps the best way to select a good telescope is to enlist the help of a local amateur astronomy club. Chances are good that at least one member already owns the telescope that you are considering and will happily share personal experiences, both good and bad. Plan on attending a club observing session, where members bring along their telescopes and set them up side-by-side to share the excitement of sky watching. To find out if there is a club near you, contact local planetariums, museums, and nature centers. You can also visit *Astronomy.com* for a directory of astronomy clubs.

Phil Harrington has faithfully kept his eyes on the sky for more than 30 years. In the meantime, he's authored several books on astronomy, including Touring the Universe Through Binoculars Atlas, *on CD ROM. Visit his web site at http://philharrington.net.*

Astronomy's top 50 under $500

To assist you with choosing the first-time scope that's just right for you, we've assembled a listing of 50 first-rate telescopes for beginners. All are far superior to any telescope you might find in a department store or on one of those 24-hour shopping channels.

To make it easier for you to compare apples with apples, and oranges with oranges, the instruments have been divided into categories according to optical design (see "Telescope Types," page 90). For each instrument, we've listed aperture, focal ratio (see "F/Number," page 93), type of mounting, standard accessories, and approximate cost. Note that the retail price may vary in some cases, but that the prices listed here are a good indication of what you might expect to pay for these telescopes in the real world.

For images and detailed specs for listed telescope models, contact each of the individual manufacturers listed below.

Model	Aperture	Focal Ratio	Tube Material	Mounting Type	Weight (lbs)	Q Index				Standard Accessories	Typical Retail Value
						Optics	Mechanics	Accessories	Overall		
Achromatic Refractors											
Celestron NexStar 60GT	2.4	12	Metal	Alt-az (GoTo)	10	2	2	3	7	20mm Kellner eyepiece 10mm Kellner eyepiece 4mm Kellner eyepiece Star diagonal Red dot unity finder GoTo control with 4,000 object database Adjustable aluminum tripod	$300
Celestron Firstscope 80 AZ	3.1	11	Metal	Alt-az	18	4	3	3	10	20mm Kellner eyepiece 10mm Kellner eyepiece 45° star diagonal Red dot unity finder Manual slow-motion controls Adjustable wooden tripod	$300
Celestron Firstscope 80 EQ	3.1	11	Metal	GEM	24	4	3	3	10	20mm Kellner eyepiece 10mm Kellner eyepiece Star diagonal Red dot unity finder Manual slow-motion controls Adjustable wooden tripod	$350
Celestron 80mm Wide View	3.1	5	Metal	Sold separately	4	3	2	2	7	20mm Plössl eyepiece 10mm Plössl eyepiece 45° star diagonal 6x30 finderscope	$200
Celestron NexStar 80GT	3.1	4	Metal	Alt-az (GoTo)	11	3	2	3	8	20mm Kellner eyepiece 10mm Kellner eyepiece Red dot unity finder GoTo mount Adjustable Metal tripod	$400
Celestron Celestron C80-HDC80-HD	3.1	11	Metal	GEM	29	5	5	3	13	20mm Plössl eyepiece Star diagonal 6x30 finderscope Manual slow-motion controls Adjustable wooden tripod	$500

Contact Info:

Celestron International
2835 Columbia Street
Torrance, CA 90503
Phone: (310) 328-9560, (800) 237-0600
Web page: http://www.celestron.com

Discovery Telescopes
615 South Tremont Street
Oceanside, California 92054
Phone: (760) 967-6598, (877) 523-4400
E-mail: scopinit@msn.com, teldisco@cs.com
Web page: http://www.discovery-telescopes.com

Edmund Scientific Co.
101 E. Gloucester Pike
Barrington, NJ 08007
Phone: (609) 547-8880
E-mail: scientifics@edsci.com
Web page: http://www.edsci.com

Meade Instruments Corp.
6001 Oak Canyon
Irvine, CA 92620
Phone: 714-756-2291
Web page: http://www.meade.com/

Novosibirsk Instruments
c/o Sovietski Collection
P.O. Box 81347
San Diego, CA 92138
Phone: (800) 442-0002, (619) 294-2000
E-mail: info@sovietski.com
Web page: http://www.sovietski.com

Orion Telescopes
P.O. Box 1158
Santa Cruz, CA 95062
Phone: (800) 447-1001 / (800) 443-1001 (in California only)
E-mail: sales@oriontel.com
Web page: http://www.telescope.com

Stargazer Steve
1752 Rutherglen Crescent
Sudbury, ON P3A 2K3 Canada
Phone: 705-566-1314
E-mail: stargazr@isys.ca
Web page: http://stargazer.isys.ca/

Telescope Types

Refractors are most easily identified by their sleek, slender appearance. The main optic lens, called the objective lens, is housed at the end of a long, thin tube. Light passes through the objective and comes to a focus toward the back end of the tube at the eyepiece. Although markedly improved over the past four centuries, this is the type of telescope that Galileo first used in 1609 to discover craters on the moon, the phases of Venus, and the four major satellites of Jupiter.

Rather than use a single lens out front as Galileo's telescope did, most modern refractors are constructed with two lenses, nested together to create what is called an achromatic objective. Achromatic objectives greatly reduce the effects of chromatic aberration — an optical effect that causes different wavelengths of visible light to come to focus at varying distances according to color. The effect generally results in fuzzy, false-color halos surrounding bright objects.

In lieu of a lens, a reflector gathers and focuses light with a large mirror (called the primary) at the bottom of its tube. The primary, with its slightly concave paraboloid shape, reflects light back up to the front of the tube, where it draws to a focus. The most popular type of reflector was invented by Isaac Newton in 1672. Newtonian reflectors have a small, flat mirror that sits at the focus point and diverts the light out to the eyepiece through a hole in the side of the tube.

Finally, catadioptric telescopes, which are sometimes called compound telescopes, combine features of the refractor and the reflector. Light first passes through a clear lens, called the corrector plate, at the front of the tube. The corrector plate slightly adjusts the light before it reflects off the primary mirror at the back of the tube. Bouncing off the primary, the light reflects toward the front of the tube, where a secondary mirror directs the light back through a hole in the primary and onto the eyepiece. — P.H.

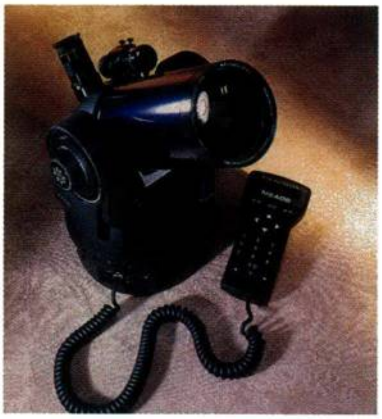
Celestron 102 Wide View	4	5	Metal	Sold separately	5	4	3	2	9	25mm Plössl eyepiece 10mm Plössl eyepiece 45° star diagonal Finder sold separately	$330
Celestron Celestron C102-AZC102-AZ	4	5	Metal	Alt-az	18	5	5	2	12	20mm Plössl eyepiece 45° star diagonal 6x30 finderscope Manual slow-motion controls Adjustable Metal tripod	$400
Discovery Telescopes RFT System 90	3.5	5	Metal	GEM	10 (5)	4	2	3	11	26mm Plössl eyepiece 10mm Plössl eyepiece 6x30 finderscope 45° star diagonal 2x Barlow lens Manual slow-motion controls Adjustable aluminum tripod and tabletop mount Soft case	$330
Meade ETX-60AT	2.4	5.8	Plastic	Fork	7	5	5	3	13	25mm Kellner eyepiece 9mm Kellner eyepiece Built-in 90° star diagonal Fork mount with built-in GOTO	$270
Meade ETX-70AT	2.8	3.5	Plastic	Fork	7	5	5	3	13	25mm Kellner eyepiece 9mm Kellner eyepiece Built-in 90° star diagonal Fork mount with built-in GOTO	$325
Meade DS-60EC	2.4	11.7	Metal	Alt-az	10	4	2	2	8	25mm Kellner eyepiece 9mm Kellner eyepiece Star diagonal 5x24 finderscope Adjustable aluminum tripod GoTo control sold separately (Autostar computer $95 extra)	$220
Meade DS-70EC	2.8	10	Metal	Alt-az	11	4	2	2	8	25mm Kellner eyepiece 9mm Kellner eyepiece Star diagonal 5x24 finderscope Adjustable aluminum tripod GoTo control sold separately (Autostar computer $95 extra)	$250
Meade DS-80EC	3.1	11.3	Metal	Alt-az	14	4	3	2	9	25mm Kellner eyepiece 9mm Kellner eyepiece Star diagonal 6x30 finderscope Adjustable aluminum tripod GoTo control sold separately (Autostar computer $95 extra)	$360
Meade DS-90EC	3.5	11.1	Metal	Alt-az	15	4	3	2	9	25mm Kellner eyepiece 9mm Kellner eyepiece Star diagonal 6x30 finderscope Adjustable aluminum tripod GoTo control sold separately (Autostar computer $95 extra)	$400
Orion Observer 70 EQ	2.8	10	Metal	GEM		3	3	2	8	25mm Kellner eyepiece 5x24 finderscope Star diagonal Manual slow-motion controls Adjustable aluminum tripod	$200
Orion ShortTube 80 Orion ShortTube 80 EQ	3.1	5	Metal	GEM	16	3	4	3	10	6x30 finderscope 25mm Kellner eyepiece 10mm Kellner eyepiece	$290

										45° star diagonal Manual slow-motion controls Adjustable aluminum tripod	
Orion ShortTube 90 Orion ShortTube 90 EQ	3.5	5.6	Metal	GEM		3	4	2	9	6x30 finderscope 26mm Plössl eyepiece Star diagonal Manual slow-motion controls Adjustable wooden tripod	$440
Orion Explorer 90	3.5	10	Metal	Alt-az	16	4	4	3	11	25mm Kellner eyepiece 10mm Kellner eyepiece 6x26 finderscope 45° star diagonal Manual slow-motion controls Adjustable aluminum tripod	$340
Orion Skywatcher 90 EQ	3.5	10	Metal	GEM	24	4	4	3	11	25mm Kellner eyepiece 10mm Kellner eyepiece 6x30 finderscope Star diagonal Manual slow-motion controls Adjustable aluminum tripod	$360
Orion SkyView Deluxe 90 Orion SkyView Deluxe 90	3.5	11.1	Metal	GEM	31	4	5	3	12	6x30 finderscope Moon filter 25mm Plössl eyepiece 9mm Plössl eyepiece Manual slow-motion controls Star diagonal Adjustable aluminum tripod	$450
Newtonian Reflectors											
Celestron Firstscope 114 EQ	4.5	9	Metal	GEM	19	4	4	2	10	20mm Kellner eyepiece 10mm Kellner eyepiece Red dot unity finder Manual slow-motion controls Adjustable aluminum tripod	$300
Celestron Firstscope 114 Short	4.5	9	Metal	GEM	16	3	4	1	8	20mm Huygenian eyepiece 6mm "F" eyepiece 5x24 finder Manual slow-motion controls Adjustable aluminum tripod	$230
Celestron Star Hopper 4.5	4.5	8	Metal	Alt-az	18	4	3	1	8	25mm Kellner eyepiece 5x24 finder	$210
Celestron NexStar 114	4.5	9	Metal	Alt-az	16	4	2	2	8	25mm Kellner eyepiece 10mm Kellner eyepiece Red dot unity finder Adjustable aluminum tripod	$500
Celestron Star Hopper 6	6	8	Cardboard	Dob	39	4	5	1	10	25mm Kellner eyepiece "Unique Balance System"	$340
Celestron Star Hopper 8	8	6	Cardboard	Dob	55	4	5	1	10	25mm Kellner eyepiece "Unique Balance System"	$430
Discovery 4.5 EQ	4.5	7.9	Metal	GEM	33 (23)	4	5	3	12	25mm Plössl eyepiece 10mm Plössl eyepiece 6x30 finder Adjustable aluminum tripod	$300
Discovery DHQ 6	6	8	Cardboard	Dob	41 (28)	5	5	3	13	25mm Plössl eyepiece 10mm Plössl eyepiece 6x30 finder Balancing plates	$340
Discovery 6 EQ	6	5	Metal	GEM	41	4	5	3	12	25mm Plössl eyepiece	$500

Is Go-To for You?

Within the past few years, a new breed of computerized alt-az mounts has broken onto the beginner telescope scene. They've been nicknamed "Go-To" mounts because that's exactly what they are designed to do. The observer doesn't have to do much more than set up the scope, turn on the power, and follow a simple alignment procedure before hundreds, even thousands, of sky objects are ready for their perusal — all with a simple touch of the keypad database.

Go-To mounts incorporate some amazing technology. But they also present a dilemma. First of all, for the same amount of money that you might spend on, say, a 2.8-inch refractor on a Go-To mount, you could purchase a 6-inch Newtonian reflector on a Dobsonian mount. The Go-To refractor has great appeal, including automatic finding and tracking. The Newtonian also has great appeal, with about 460% more light-gathering surface area, which can mean the difference between seeing an object and missing it entirely.



The latest in telescope technology brings the sky to your fingertips.

Go-To mounted scopes are great for astronomy newcomers, since they significantly cut the amount of time spent locating each target. But they also eliminate the need for new astronomers to learn how to read charts and locate objects in the sky. That may not sound too bad, but for many astronomers, learning the night sky is what amateur astronomy is all about. In the end, only you can decide whether Go-To is the way to go. — P.H.

Telescope Quality Index

We've assigned each telescope a quality index based on several criteria, including optical quality, mechanical quality, and quality of included accessories. The optical index (rated 1 – 5) is based on the telescope's overall performance with the moon, planets, and deep-sky objects. The mechanical index (also rated 1 – 5) is based on the quality of the mount and other mechanical components, such as the focuser. The accessory index (rated 1 – 3) carries slightly less weight, since it's much easier to add accessories than it is to replace poor optics or a shaky mount. Finally, the indices are tallied to give each telescope an overall score, with a maximum of 13. — P.H.

					(30)					10mm Plössl eyepiece 6x30 finder Polar alignment scope Adjustable aluminum tripod	
Discovery DHQ 8	8	6	Cardboard	Dob	46 (28)	5	5	3	13	25mm Plössl eyepiece 10mm Plössl eyepiece 6x30 finder Balancing plates	$450
Edmund Astroscan 2001	4.13	4.2	Plastic	Ball	13	4	4	2	10	28mm RKE eyepiece "Open Sight Target Finder" Table-top base Shoulder strap	$300
Meade DS114EC	4.5	8	Metal	Alt-az	18	5	3	2	10	25mm Kellner eyepiece 9mm Huygenian eyepiece 6x30 finder Adjustable aluminum tripod GoTo control sold separately (Autostar computer $95 extra)	$360
Meade DS127EC	5	8	Metal	Alt-az	20	5	3	2	10	25mm Kellner eyepiece 9mm Huygenian eyepiece 6x30 finder Adjustable aluminum tripod GoTo control sold separately (Autostar computer $95 extra)	$430
Meade Starfinder 6 Dob	6	8	Cardboard	Dob	34 (20)	5	3	1	9	26mm Super Plössl eyepiece 5x24 finder Deluxe version includes: metal focuser 6x30 finder 26mm and 9.7mm Super Plössls (Deluxe version $375)	$320
Meade Starfinder 8 Dob	8	6	Cardboard	Dob	44 (26)	5	3	1	9	26mm Super Plössl eyepiece 5x24 finder Deluxe version includes: Metal focuser 6x30 finder 26mm and 9.7mm Super Plössls (Deluxe version $475)	$420
Novosibirsk Instruments TAL-1 (Sovietski 4.3)	4.3	7.3	Metal	GEM	42	4	5	3	12	6x30 finder 15mm Kellner eyepiece 25mm Symmetrical eyepiece 3x Barlow lens Six glass color filters Sun projection screen Camera bracket for piggyback photography Pedestal Hardwood storage case	$350
Novosibirsk Instruments TAL-120 (Sovietski 4.8)	4.7	6.7	Metal	GEM	44	4	5	3	12	6x30 finder 15mm Kellner eyepiece 25mm Symmetrical eyepiece 3x Barlow lens Six glass color filters Sun projection screen Camera bracket for piggyback photography Pedestal Hardwood storage case	$300
Novosibirsk Instruments TAL-2M (Sovietski 6)	6	8	Metal	GEM	88	4	5	3	12	8x50 finder 15mm Kellner eyepiece 25mm Plössl eyepiece	$500

										3x Barlow lens Six glass color filters Sun projection screen Camera bracket for piggyback photography Pedestal Hardwood storage case	
Orion ShortTube 4.5 EQ	4.5	8.8	Metal	GEM		2	3	2	7	25mm Kellner eyepiece 10mm Kellner eyepiece 5x24 finder Slow-motion controls Adjustable wooden tripod	$200
Orion SkyView Deluxe 4.5	4.5	8	Metal	GEM	32	4	5	3	12	25mm Plössl eyepiece 9mm Plössl eyepiece 6x30 finder Moon filter Manual slow-motion controls Adjustable aluminum tripod	$380
Orion Telescopes XT-4.5	4.5	8	Metal	Dob	18	4	5	3	12	25mm Plössl eyepiece 9mm Plössl eyepiece 6x30 finderscope R&P focuser	$230
Orion Telescopes SpaceProbe 130ST	5.1	5	Metal	GEM	27	4	4	3	11	6x30 finderscope 25mm Kellner eyepiece 10mm Kellner eyepiece Slow-motion controls R&P focuser	$350
Orion Telescopes SpaceProbe 130	5.1	6.9	Metal	GEM	32	4	4	3	11	25mm Kellner eyepiece 10mm Kellner eyepiece 6x30 finderscope Slow-motion controls R&P focuser Adjustable wooden tripod	$250
Orion SkyView Deluxe 6	6	5	Metal	GEM	39	4	5	3	12	25mm Plössl eyepiece 9mm Plössl eyepiece 6x30 finder Moon filter Manual slow-motion controls Adjustable aluminum tripod	$500
Orion Telescopes XT-6	6	8	Metal	Dob	37 (24)	5	5	3	13	25mm Plössl eyepiece 9mm Plössl eyepiece 6x30 finder Moon filter Eyepiece rack	$370
Orion Telescopes XT-8	8	6	Metal	Dob	42 (23)	5	5	3	13	25mm Plössl eyepiece 9mm Plössl eyepiece 6x30 finder Moon filter Eyepiece rack	$500
Stargazer Steve SGR-4	4.25	7.1	Cardboard	Alt-az	17	5	5	2	12	17mm Plössl eyepiece Rigel QuikFinder Wooden tripod	$310
Stargazer Steve 4.25 (kit)	4.25	10	Cardboard	Dob	16	5	5	2	12	10mm Kellner eyepiece Aiming sight tube All assembly components Instruction manual and video	$230
Stargazer Steve 6 (kit)	6	8	Cardboard	Dob	24	5	5	2	12	17mm Plössl eyepiece Rigel QuikFinder All assembly components Instruction manual and video	$380

F/Number

Another factor to consider when shopping for your first telescope is the focal ratio (sometimes written f/ratio or f/number). This simple measure (obtained by dividing the focal length of the telescope by the aperture of the objective) gives you an idea for the kind of observing that best suits a particular telescope.

Astronomers often speak of f/ratios in terms of a telescope's "speed." Slow telescopes have f/ratios between f/8 and f/15, while fast telescopes have f/ratios between f/4 and f/8. The origin of this terminology comes from astrophotography. Fast telescopes allow for shorter exposure times than slow telescopes.

Because magnification is directly related to focal length, slow telescopes also tend to yield more magnification for the same aperture. For example, an 8-inch f/10 scope yields 80 power with a 1-inch eyepiece, while an 8-inch f/4 scope yields only 32 power for the same eyepiece. In general, fast scopes are better for wide-angle objects like galaxy clusters, whereas slow scopes afford high-power views of globular clusters and planets. Again, it's a good idea to know the type of observing you plan to do. — P.H.

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Alaskan aurora photograph by Mike O'Leary

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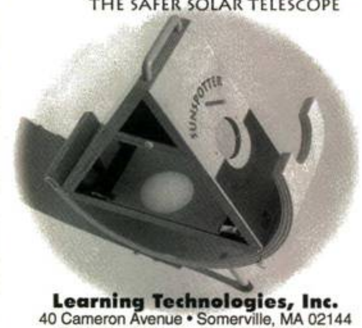

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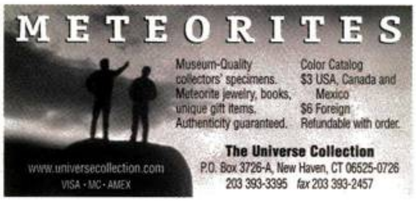

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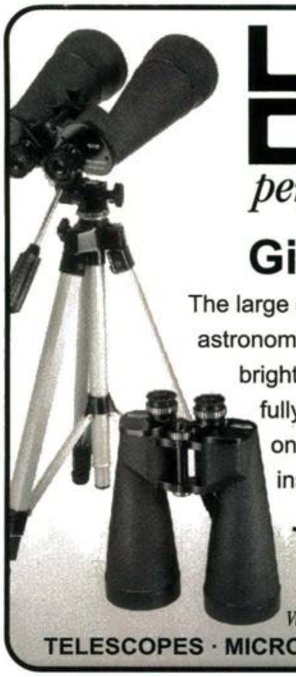

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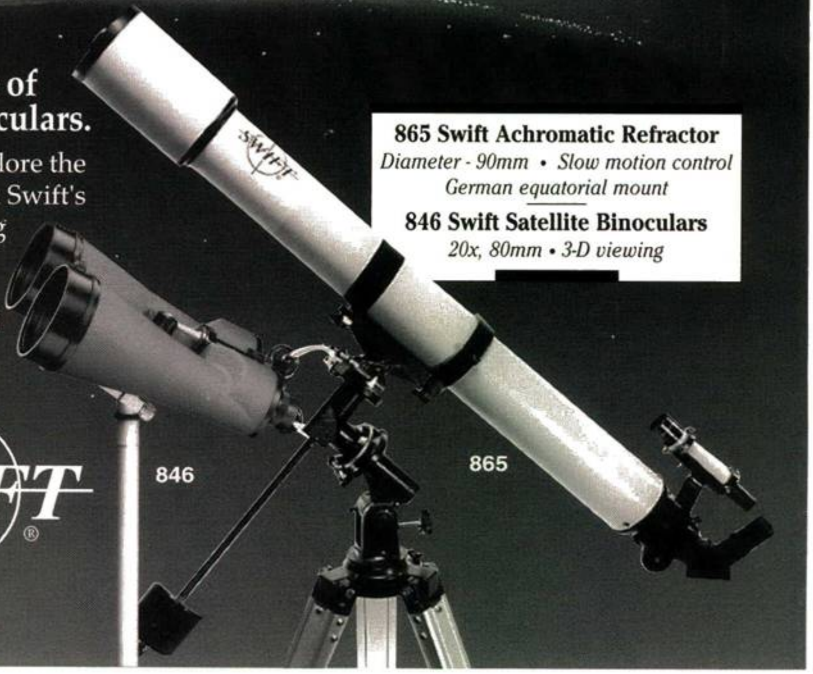

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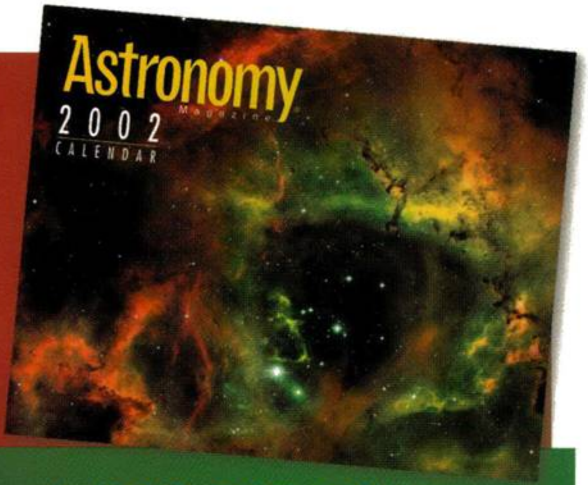

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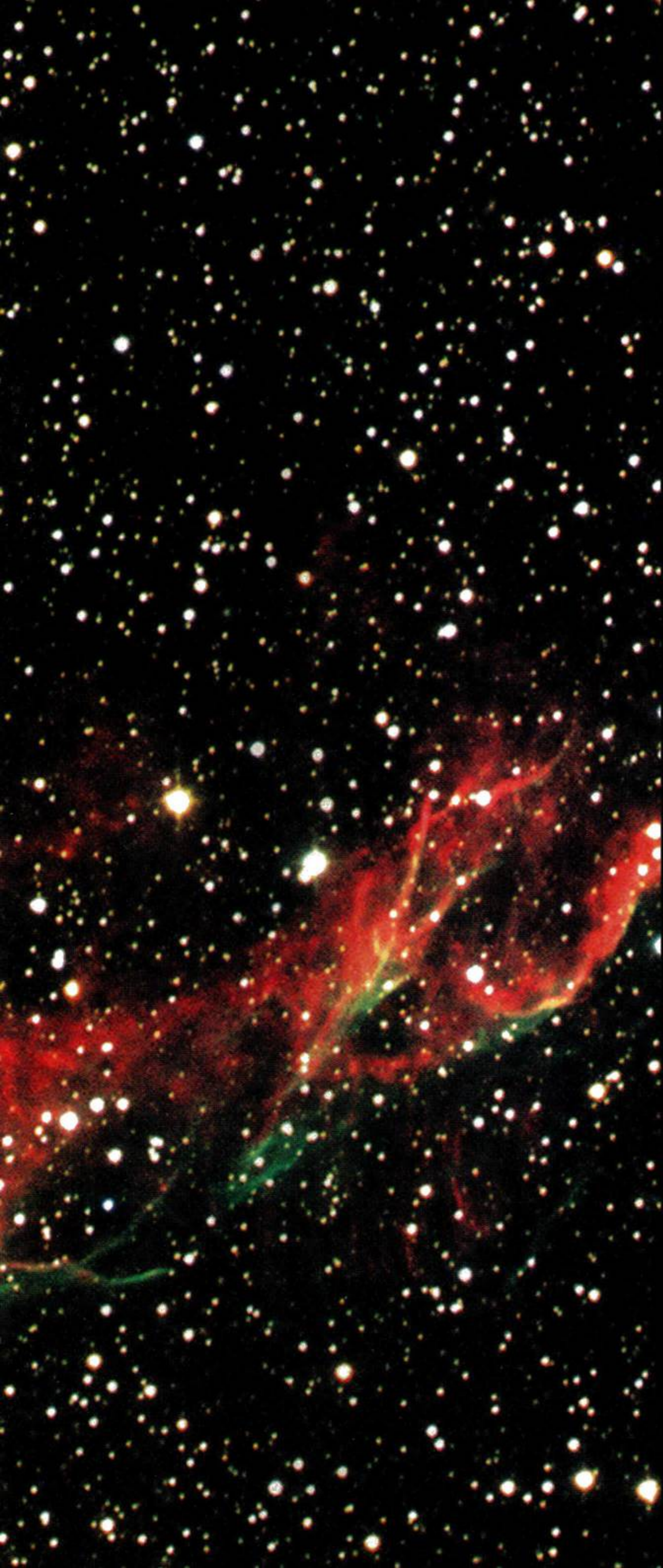

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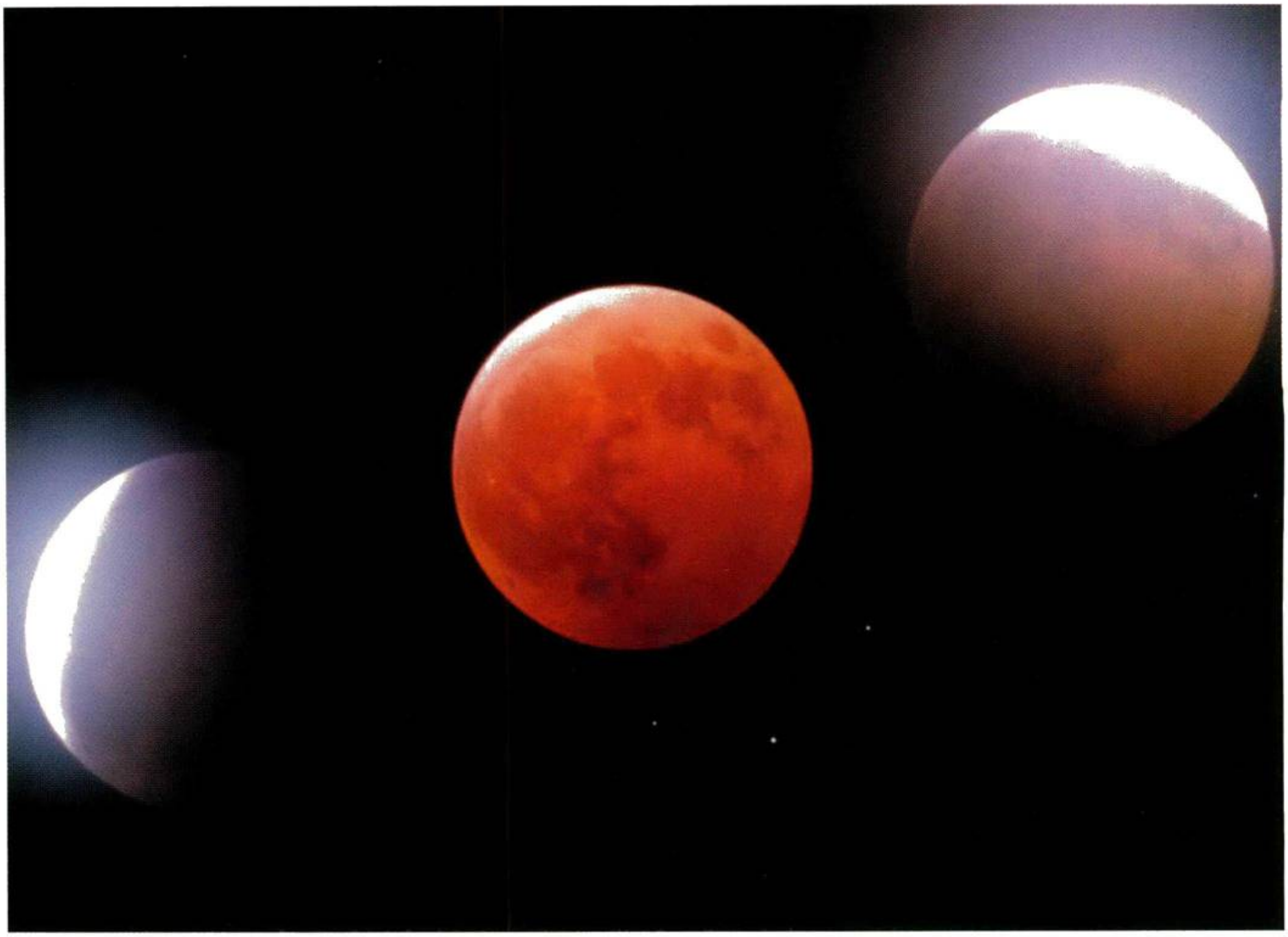
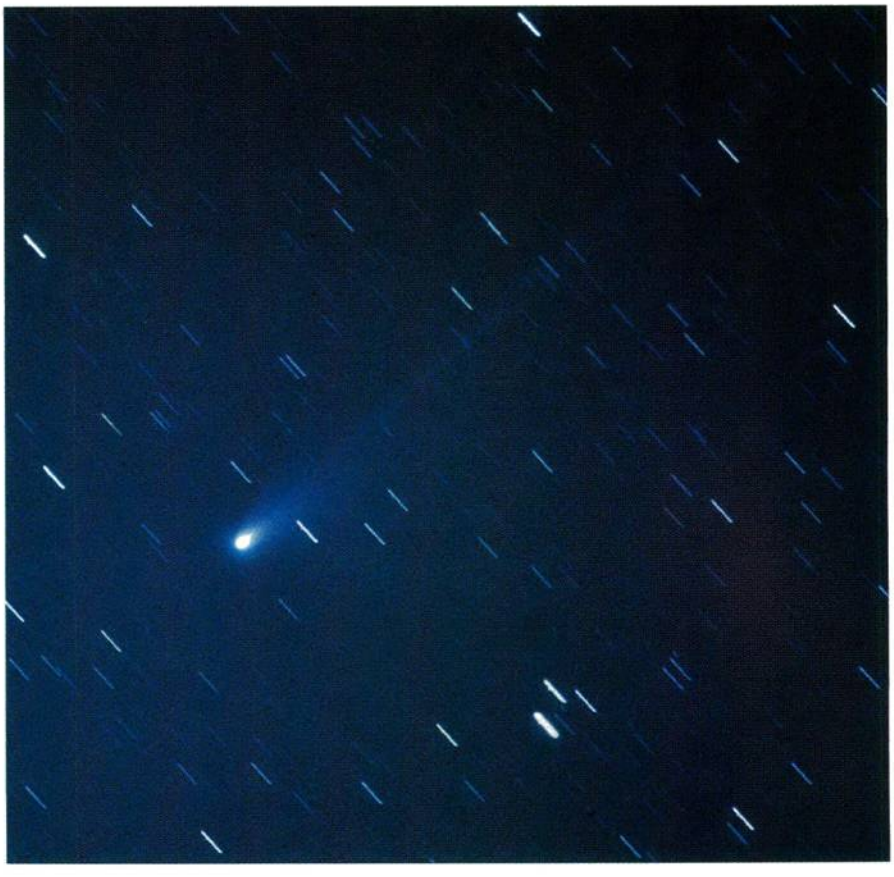
The Veil Nebula

CLIFF WRIGHT

(18.2-inch f/2.8 reflector, SBIG ST-8e CCD camera, composite of four exposures)





Lunar Eclipse of January 9, 2001

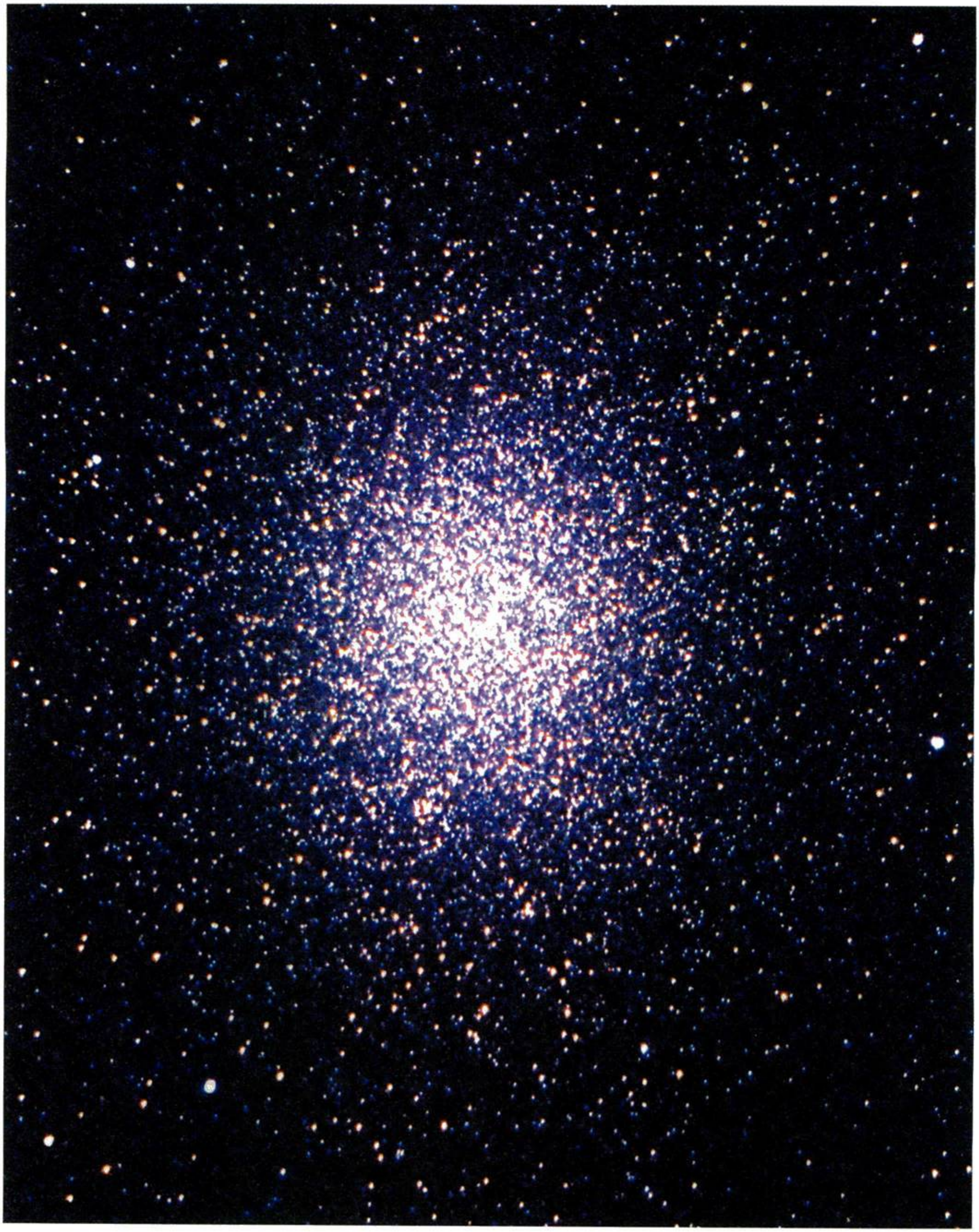
JON TEUS

(8-inch f/4.5 reflector, Ektachrome 200 film processed at ISO 400, partial phases shot at 1-second and totality at 6 seconds, taken January 9, 2001, from Guipuzcoa, Spain)

Comet LINEAR (C/1999 S4)

ALBERTO LEVY

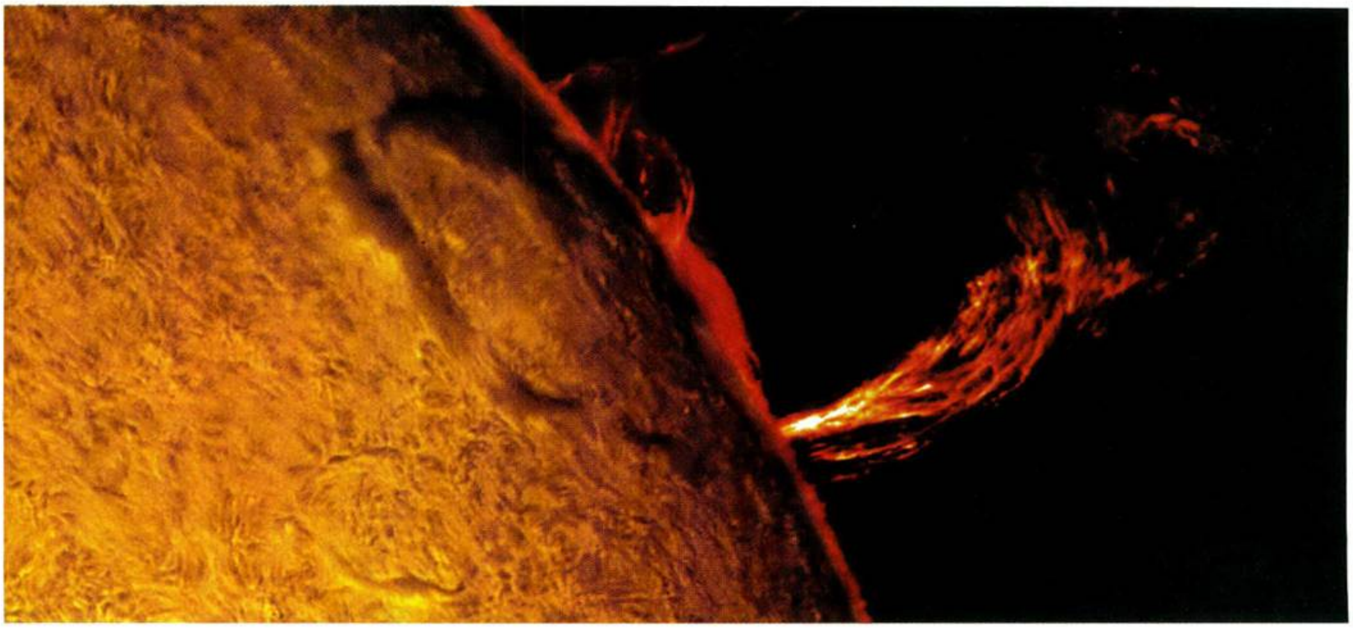
(4-inch f/5 refractor, hypersensitized Ektachrome 200 film, 15-minute exposure taken July 23, 2000)



Globular Star Cluster Omega Centauri

JAMES R. FOSTER

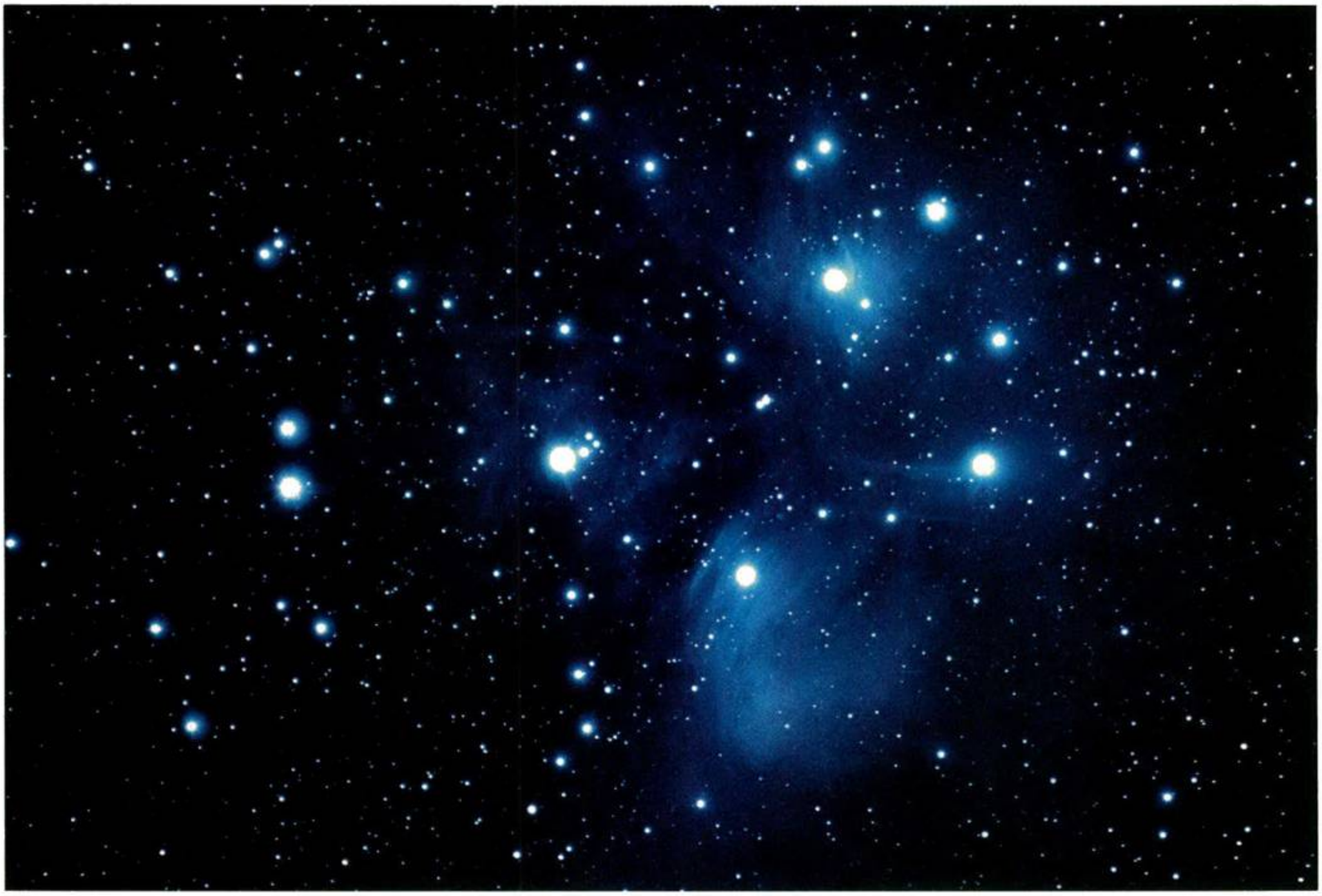
(11-inch SCT at f/11, Fuji HG 400 film, 12-minute exposure)



Magnificent Solar Prominence

JACK NEWTON

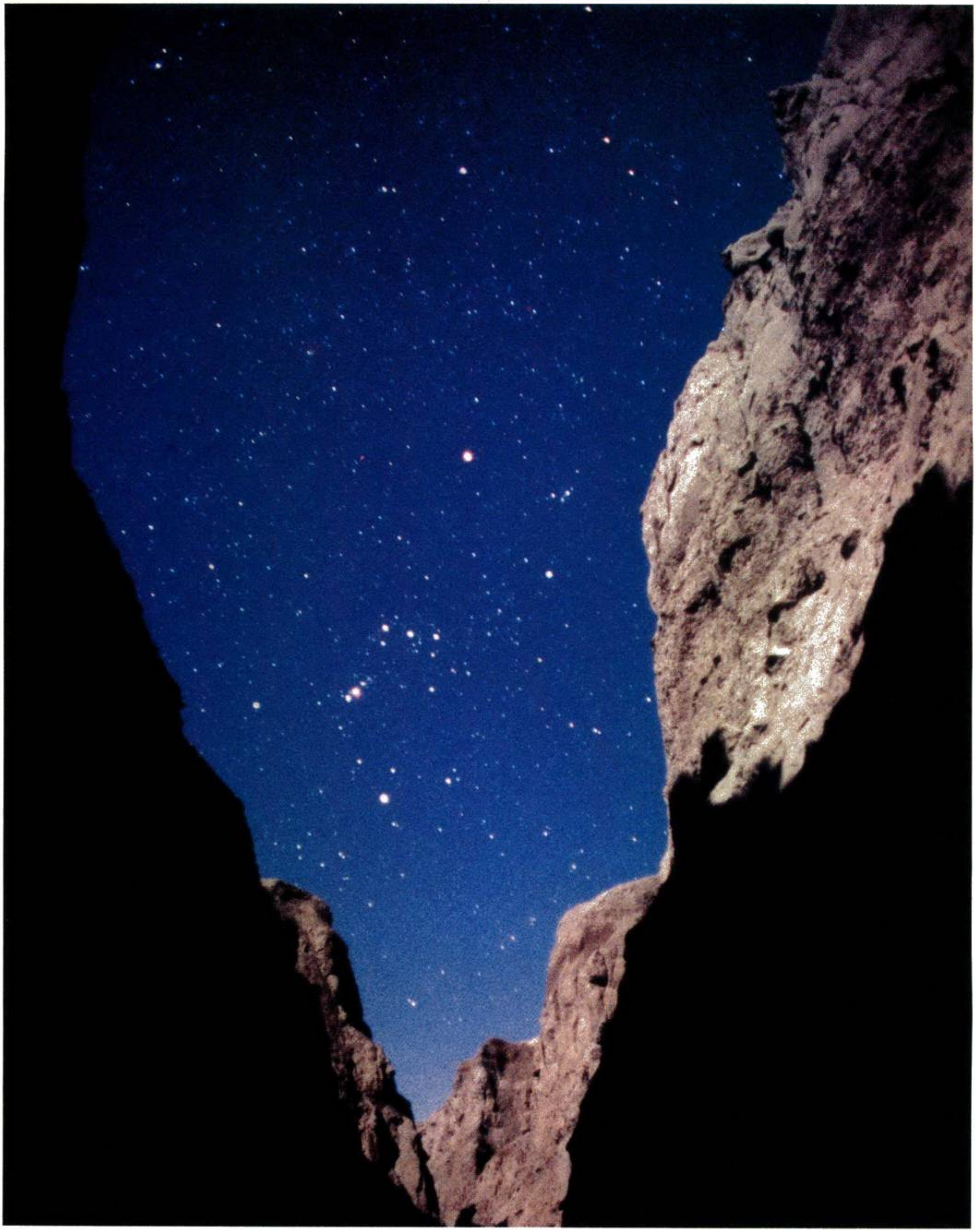
(5-inch apochromatic refractor, Pictor 1616XTE CCD camera, Coronado H-alpha filter, taken December 7, 2000)



The Pleiades (M45) Star Cluster in Taurus

JASON WARE

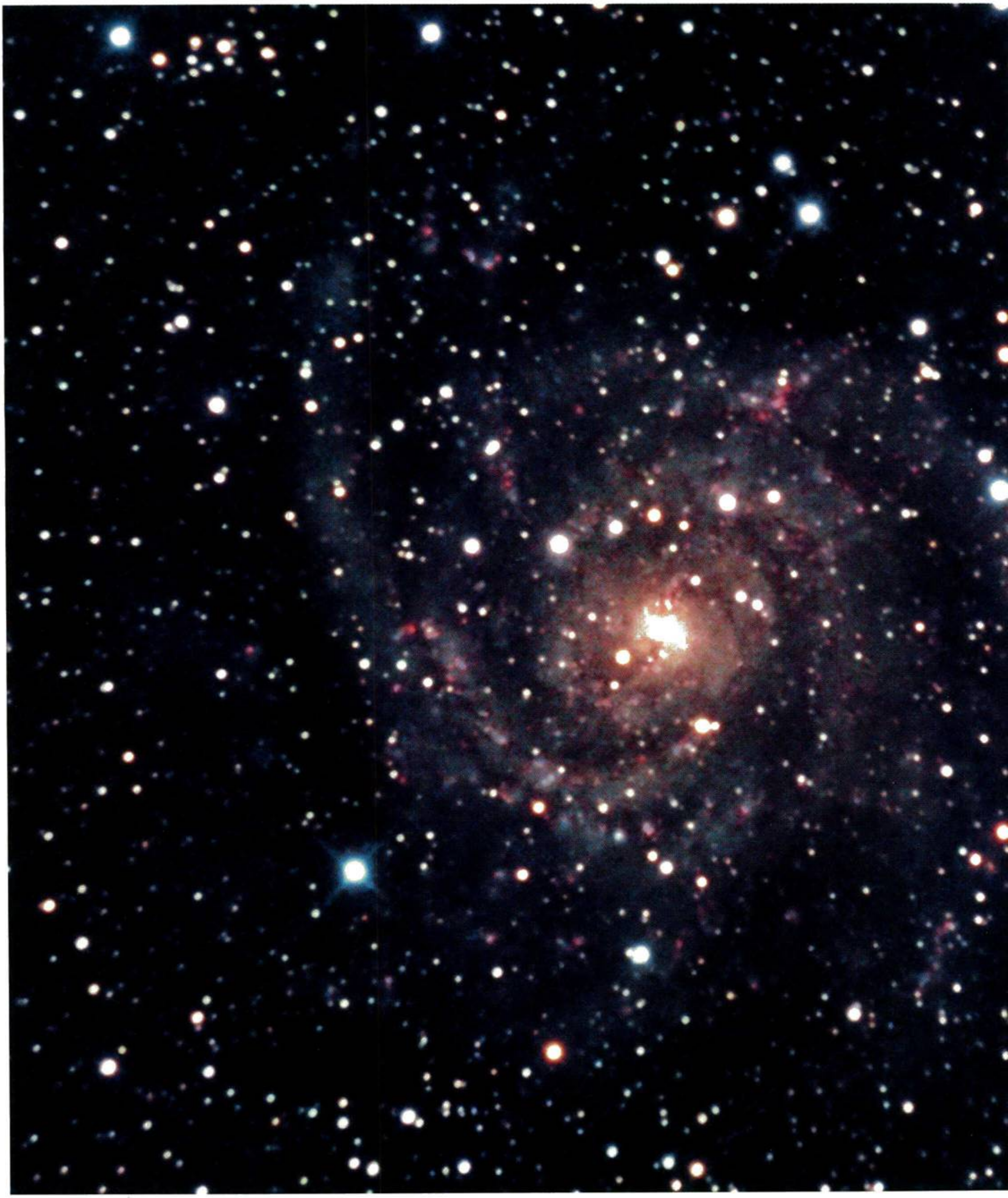
(6-inch f/9 apochromatic refractor, Fuji HG 400 film, 120 format, composite of two 60-minute exposures)



Orion over the Anza-Borrego Desert

JERRY SCHAD

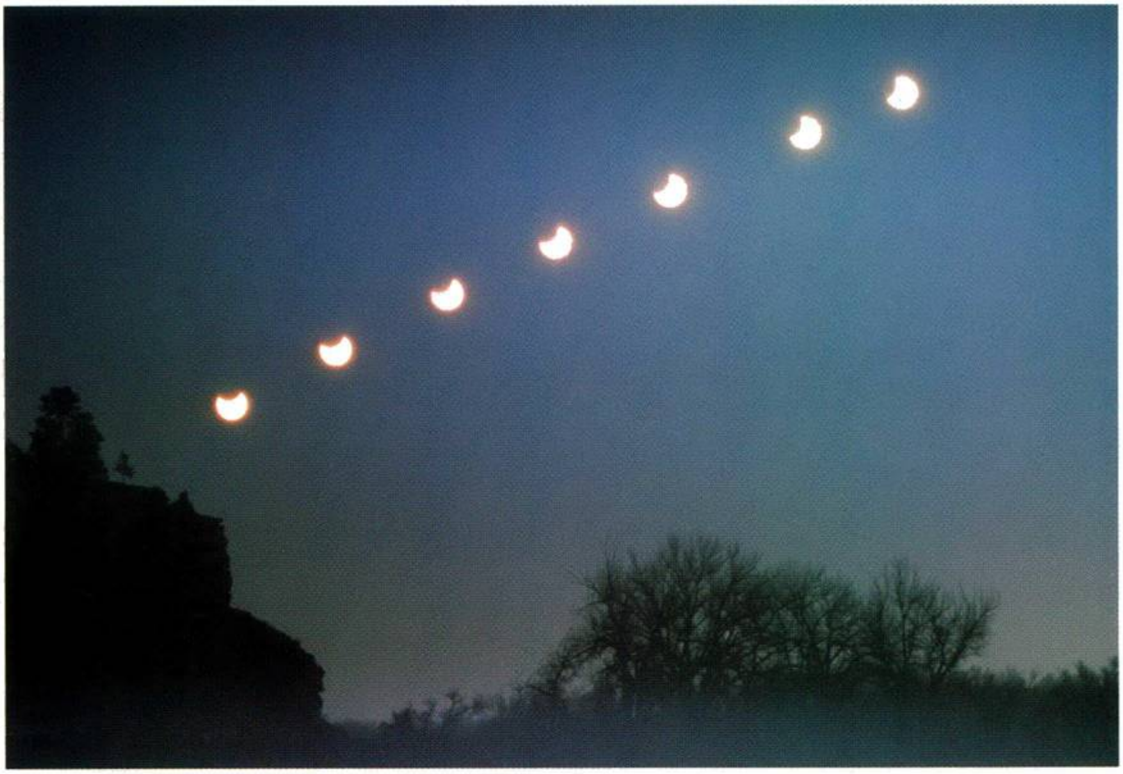
(24mm lens at f/1.7, P1600 film at ISO 3200, 35-second exposure; illuminated by moonlight)

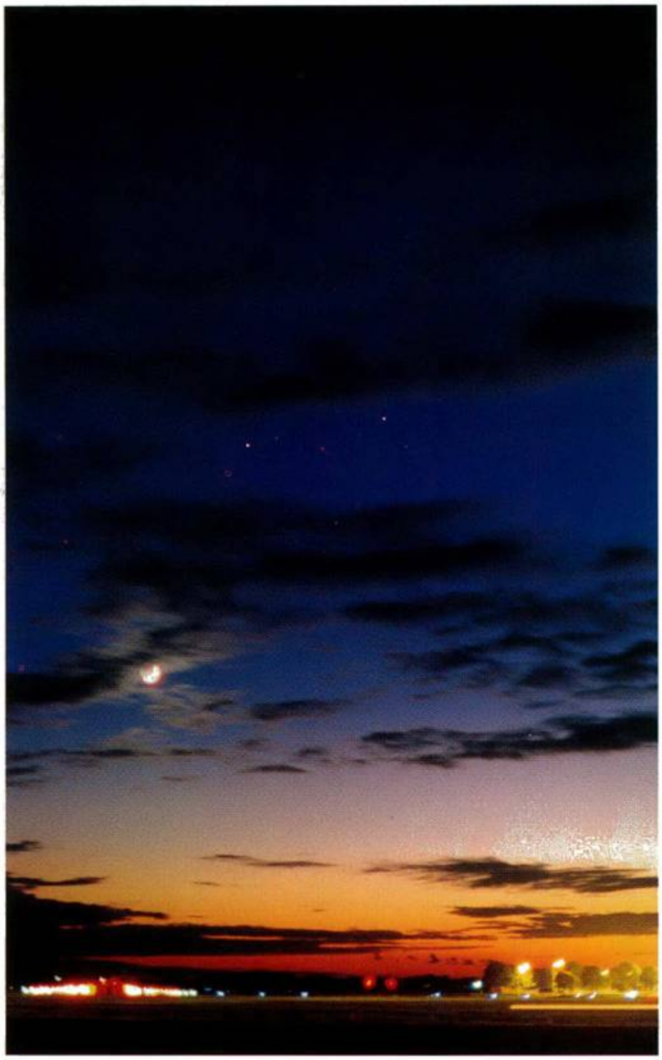


Local Group Galaxy IC 342 in Camelopardalis

JAMES R. FOSTER

(13.1-inch reflector at f/7.5, composite of 90- and 75-minute exposures on hypersensitized Kodak PPF film and 197-minute exposure on hypersensitized Tech Pan film)





Solar Eclipse on Christmas Day

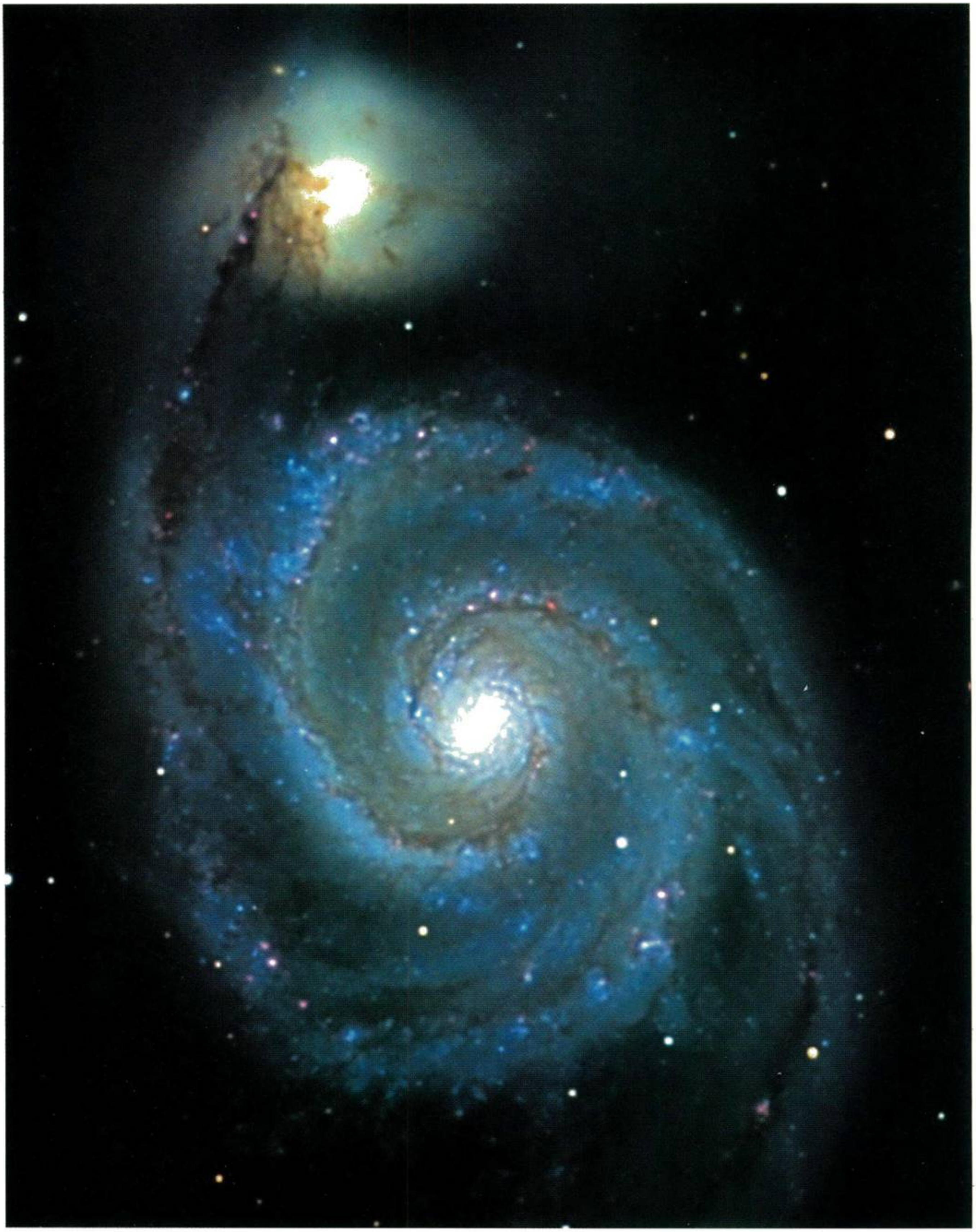
JOHN MCNEAL

(composite photograph made on December 25, 2000, from Pompeys Pillar, Montana)

Moon and Mercury in Conjunction

RANDALL WEHLER

(50mm lens at f/2, Elitechrome 100 film, 5-second exposure taken June 4, 2000)



The Whirlpool Galaxy (M51) in Canes Venatici

ADAM BLOCK

(16-inch f/6.3 SCT, SBIG ST-8 CCD camera, LRGB image with 84-minute luminance, 34-minute red, 34-minute green, and 64-minute blue exposures)

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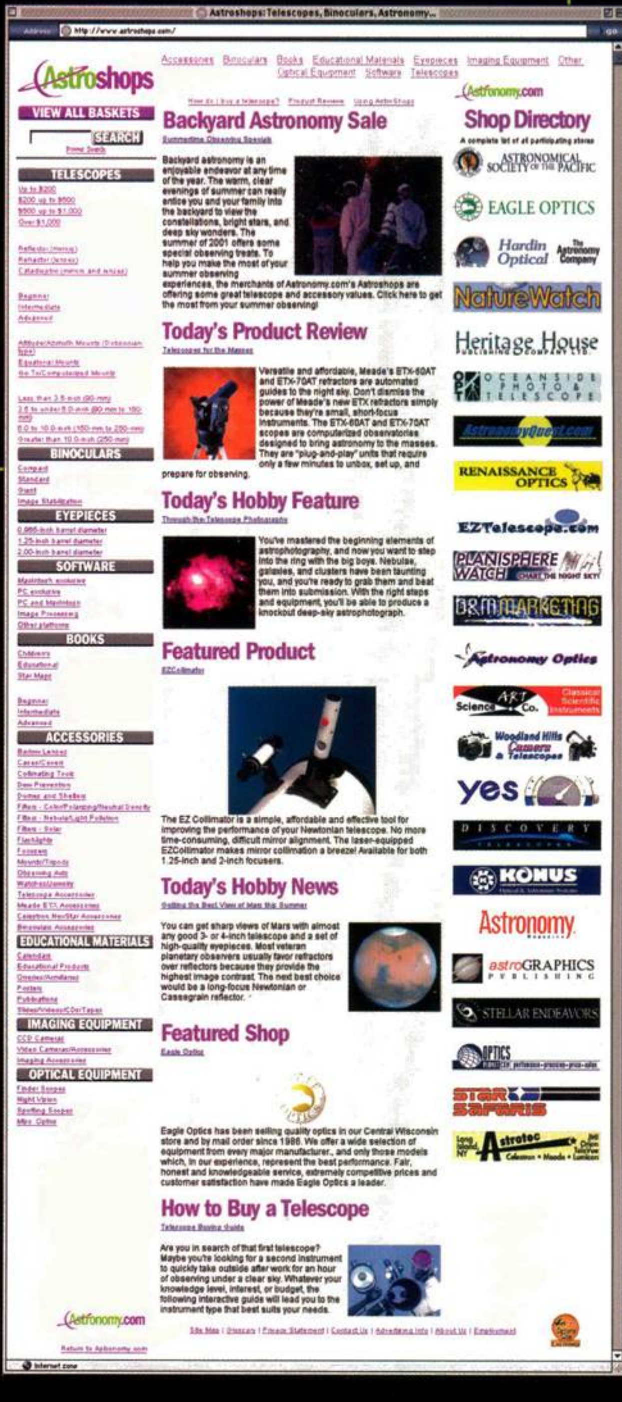
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You can get sharp views of Mars with almost any good 3- or 4-inch telescope and a set of high-quality eyepieces. Most veteran planetary observers usually favor refractors over reflectors because they provide the highest image contrast. The next best choice would be a long-focus Newtonian or Cassegrain reflector.

Featured Shop

Eagle Optics

Eagle Optics has been selling quality optics in our Central Wisconsin store and by mail order since 1986. We offer a wide selection of equipment from every major manufacturer., and only those models which, in our experience, represent the best performance. Fair, honest and knowledgeable service, extremely competitive prices and customer satisfaction have made Eagle Optics a leader.

How to Buy a Telescope

Telescope Buying Guide

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